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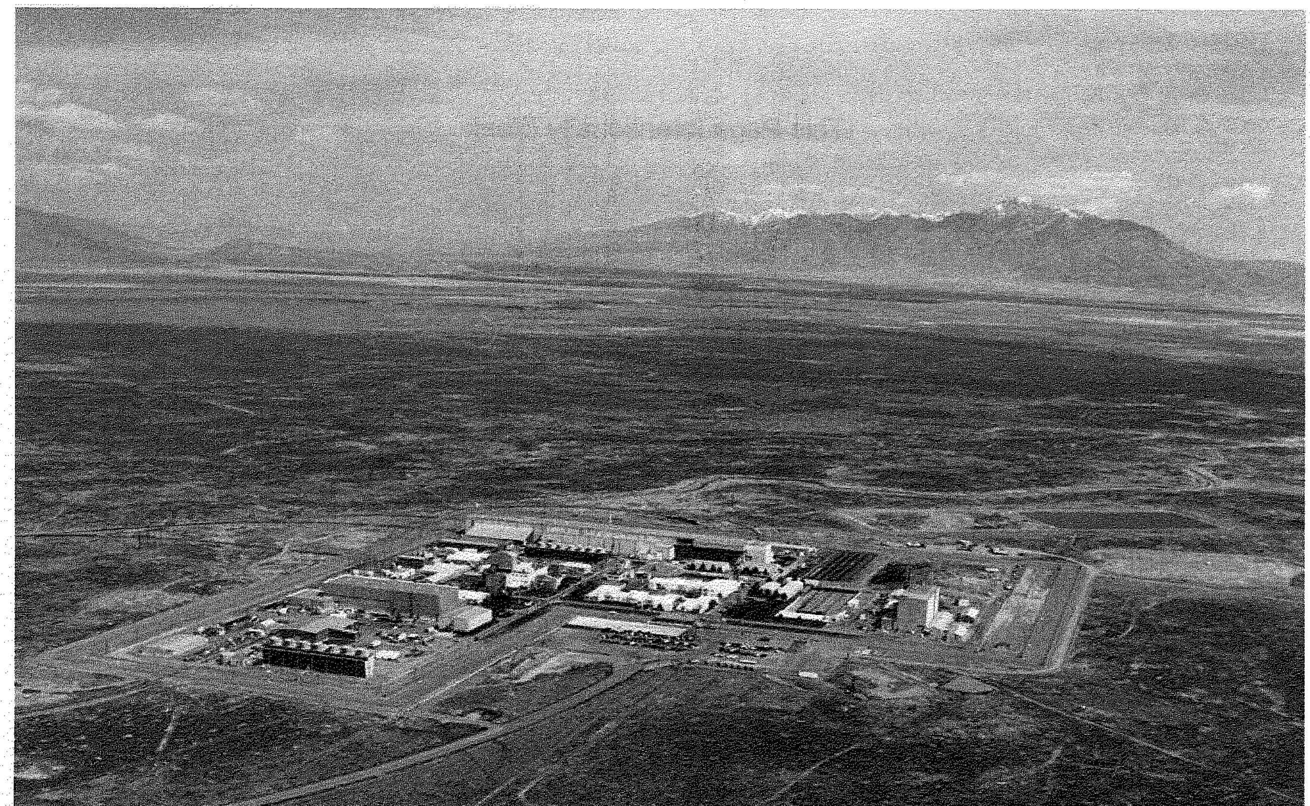
Five-Year Review Document for the Naval Reactors Facility Inactive Landfill Areas



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Five-Year Review Document

for the

Naval Reactors Facility

Inactive Landfill Areas

February 2001

By

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List of Acronyms

A1W	Large Ship Reactor Prototype (1st Aircraft Carrier design by Westinghouse)
ARAR	Applicable or Relevant and Appropriate Requirements
asl	Above Sea Level
bls	Below Land Surface
BNA	Base Neutral Acids
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CFR	Code of Federal Regulations
DFA	Design, Follow, and Administrative
DOE	Department of Energy
ECF	Expended Core Facility
EPA	Environmental Protection Agency
°F	Degrees Fahrenheit
F/L	Fluvial/Lacustrine
FFA/CO	Federal Facilities Agreement and Consent Order
GMN	Groundwater Monitoring Network
HI	Hazard Index
ICR	Increased Cancer Risk
IDHW	Idaho Department of Health and Welfare
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technological Center
IWD	Industrial Waste Ditch
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
MEMO	Monitoring Efficiency Model
μ	Micro (a prefix denoting a one-millionth part or 10^{-6})
mg	Milligrams
N	Nitrogen
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NPL	National Priorities List
NR	Naval Reactors
NRF	Naval Reactors Facility
O&M	Operations and Maintenance
OU	Operable Unit
PAH	Polynuclear Aromatic Hydrocarbons
PCE	Tetrachloroethylene
pCi	Picocurie; one trillionth (10^{-12}) of a curie, a measure of the amount of radioactivity
pCi/g	Picocuries Per Gram
pCi/L	Picocuries Per Liter
ppb	Parts Per Billion
ppbv	Parts Per Billion by Volume
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act.
RD/RAWP	Remedial Design/Remedial Action Work Plan
RI/FS	Remedial Investigation and Feasibility Study
S1W	Submarine Thermal Reactor Prototype (1st Submarine design by Westinghouse)

S5G	Submarine Reactor Plant Prototype (5th Submarine design General Electric)
SL	Sewage Lagoon
SRP	Snake River Plain
SRPA	Snake River Plain Aquifer
TCA	1,1,1-Trichloroethane
TCE	Trichloroethylene
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOX	Total Organic Halogens
TRA	Test Reactor Area
$\mu g/m^3$	Micrograms per Cubic Meter
$\mu S/cm$	Microseimens per Centimeter
USGS	United States Geological Survey
VOC	Volatile Organic Compound
v/v	Volume of Constituent Per Volume of Sample
WAG	Waste Area Group
WEC	Westinghouse Electric Company
WRIR	Water Resource Investigation Report

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Executive Summary

The Idaho National Engineering and Environmental Laboratory (INEEL), located in southeastern Idaho, is a government-owned reservation managed by the U.S. Department of Energy (DOE). It was listed on the National Priorities List (NPL) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in November 1989. In accordance with the requirements of CERCLA, the Environmental Protection Agency (EPA), the State of Idaho, and DOE negotiated a Federal Facility Agreement and Consent Order (FFA/CO). This agreement described the methods by which DOE, EPA, and the State of Idaho would implement CERCLA activities at the INEEL.

To aid in the management of this project, the INEEL was divided into Waste Area Groups (WAGs) and the WAGs were further divided into Operable Units (OUs). The FFA/CO and associated Action Plan identified the appropriate level of investigation for each OU. Under direction of the Action Plan, OUs 8-05 and 8-06 (Inactive Landfill Areas) at the Naval Reactors Facility (NRF) were investigated as "Track 2" sites. The investigation resulted in the identification of three former inactive landfill areas that required remedial actions to ensure continued protection of human health and the environment. A Record of Decision (ROD) was signed in 1994, which implemented the presumptive remedy for municipal type landfills at NRF. As part of the presumptive remedy, engineered soil covers were constructed over the inactive landfill areas and monitoring of soil-gas and groundwater was implemented.

Since waste remains on site after the completion of remedial actions, CERCLA requires a Five-Year Review to evaluate the effectiveness of the remedies selected and to determine if the remedies remain protective to human health and the environment. This document provides the Five-Year Review for the NRF Inactive Landfill Areas. The EPA guidance manual for performing and documenting Five-Year Reviews was followed. The review included evaluating past monitoring data (soil gas and groundwater), remedy performance, risk assessments, and any other aspects that may have changed the effectiveness of the selected remedies or provided evidence that the selected remedies were not performing as desired.

This Five-Year Review concludes that the selected remedies remain protective of human health and the environment. Based on the data gathered and the information presented in this document, a slight modification to the groundwater monitoring program is suggested. Several chemical and radiological parameters are proposed to be removed from the monitoring program, since little added benefit is gained from these analyses and some cost savings can be realized by eliminating these parameters. In addition, a reduction in the frequency of collecting groundwater samples is proposed beginning in 2003, provided that groundwater data collected over the next two years remains consistent with prior data. This will reduce monitoring costs while not compromising the effectiveness of the monitoring program.

The next OU 8-05/06 Five-Year Review is scheduled for 5 years from the issuance of this document (2006); however, this Review may be combined with the NRF Comprehensive Five-Year Review for OU 8-08, which is scheduled for June 2004, if this appears more efficient.

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1.0 Introduction

Bechtel Bettis, Inc. operates the Naval Reactors Facility (NRF) for the U. S. Department of Energy (DOE), Office of Naval Reactors. In 1991, DOE signed a Federal Facilities Agreement and Consent Order (FFA/CO) with the Idaho Department of Health and Welfare, (IDHW) and the U. S. Environment Protection Agency (EPA) Region 10, which initiated NRF's participation in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) at the Idaho National Engineering and Environmental Laboratory (INEEL).

Bechtel Bettis, on behalf of the signatories of the FFA/CO, has conducted a Five-Year Review of the remedial actions implemented for the Inactive Landfill Areas at NRF, Butte County, Idaho. The purpose of the Five-Year Review is to determine whether the remedy remains protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review Reports. In addition, Five-Year Review Reports identify deficiencies found during the review, if any, and identify recommendations to address them.

This review is required by statute. Five-Year Reviews must be implemented consistent with CERCLA and the National Oil and Hazardous Substance Pollution Contingency Plan (NCP). CERCLA §121(c), as amended, states:

> If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial actions no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented.

The NCP part 300.430(f)(4)(ii) of Code of Federal Regulations (CFR) states:

> If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such actions no less often than every five years after the initiation of the selected action.

This is the first Five-Year Review for the NRF Inactive Landfill Areas. This review covers three inactive Landfill Areas designated as 8-05-1, 8-05-51, and 8-06-53 in prior CERCLA documentation. As part of this review, the NRF Groundwater Monitoring Well System and the NRF Soil Gas Monitoring Well System are also addressed. The trigger for this statutory review is the contract mobilization date for the landfill covers construction project which was February 26, 1996.

2.0 Site Chronology

Table 1 summarizes the chronology of events for the NRF Inactive Landfill Areas, groundwater monitoring wells, and soil gas wells. This list includes construction dates and key regulatory dates.

Table 1 Chronology of NRF Inactive Landfills Areas

Date	Event
1960	Estimated initial closure of landfill site 8-05-1
1963	Estimated initial closure of landfill site 8-05-51
1970	Estimated initial closure of landfill site 8-06-53
Circa 1987	Initial post closure discovery of landfill problem
November 1989	NPL[1] listing (Whole INEEL)
November 1993	1st Track 2 Investigation complete (8-05-1 and 8-05-51)
April 1994	2nd Track 2 Investigation complete (8-06-53)
September 1994	Record of Decision signed
October 1994	Remedial design begins
August 1995	Remedial design complete
May 1995	Groundwater monitoring wells construction begins
September 1995	Groundwater monitoring wells construction complete
February 1996	Landfill covers construction begins
September 1996	Landfill covers construction complete
February 1996	Soil gas monitoring wells construction begins
June 1996	Soil gas monitoring wells construction complete
February 2001	Five-Year Review Report issued

1 NPL - National Priorities List (list of sites requiring evaluation under CERCLA)

3.0 Background and Physical Characteristics

3.1 Site Location and Demography

3.1.1 Idaho National Engineering and Environmental Laboratory

The Idaho National Engineering and Environmental Laboratory (INEEL) is a government facility managed by the U.S. Department of Energy (DOE), located 32 miles west of Idaho Falls, Idaho, and occupies 894 square miles (mi^2) of the northeastern portion of the Eastern Snake River Plain. Facilities at the INEEL are primarily dedicated to nuclear research, development, and waste management, but also have recently emphasized environmental research.

3.1.2 Naval Reactors Facility

The Naval Reactors Facility (NRF) is located on the west central side of the INEEL, as shown on Figure 1, approximately 50 miles west of Idaho Falls, Idaho. NRF was established in 1949 as a testing site for the Naval Nuclear Propulsion Program. The Westinghouse Electric Company operated NRF for DOE, Office of Naval Reactors from 1949 through the fall of 1998, at which time site operations were turned over to Bechtel Bettis, Inc. NRF covers 7 square miles, of which 80 acres are developed. At various times, the site was occupied by up to 3,300 people. Approximately 620 Bechtel employees and 190 long-term subcontractor and DOE employees are currently working at NRF. The nearest public roads to NRF are approximately 7 miles west, 10 miles north, and 10 miles south.

3.1.3 Ecological Characteristics

Fifteen distinctive vegetative cover types have been identified at the INEEL. The vegetation cover class at NRF is primarily shrub-steppe flats with sagebrush being the dominant species and providing the majority of habitat. No threatened, endangered, or otherwise regulated flora is known to be present in the NRF area. The variety of habitats on the INEEL supports numerous species of reptiles, birds, and mammals. Several bird species warrant special concern because of their threatened status or sensitivity to disturbance. NRF is not known to be within a critical habitat for endangered or threatened species. The Threatened Fish and Wildlife Act does not identify any fish or wildlife species of concern at NRF. Migratory waterfowl frequent wetted areas near NRF. The developed area of NRF is an industrial area with continuous human activity that contains little suitable habitat for most endangered, threatened, or sensitive species.

3.2 Site Physical Geology

3.2.1 Overview

The INEEL is located on the northeastern portion of the Eastern Snake River Plain, a volcanic plateau that is composed primarily of volcanic rocks and relatively minor amounts of sediments. Underlying the INEEL is a series of basaltic flows containing sedimentary interbeds. The Snake River Plain Aquifer (SRPA) is the largest potable aquifer in Idaho, and underlies the Eastern Snake River Plain and the INEEL. The aquifer is approximately 200 miles long and 50 miles wide, and covers an area of approximately 9,600 mi^2. The depth to the SRPA at the INEEL varies from approximately 200 feet in the northeastern corner to approximately 900 feet in the southeastern corner. The distance between these extremes is 42 miles. The EPA designated

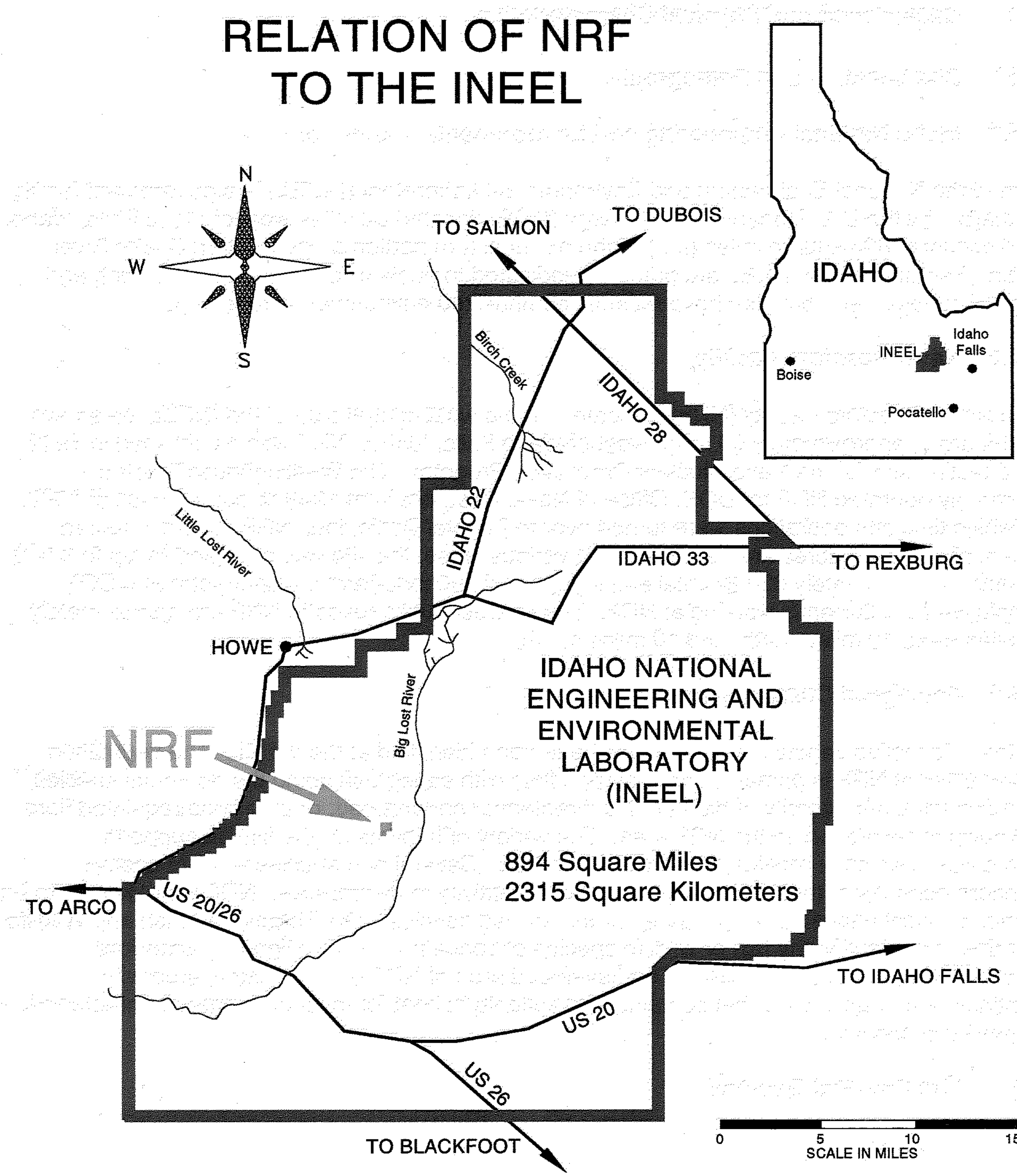

Figure 1 Location of the Naval Reactors Facility (Waste Area Group 8)

the SRPA as a sole-source aquifer under the Safe Drinking Water Act on October 7, 1991. The aquifer possesses a high hydraulic conductivity on a large scale because of the presence of fractures in the basalt. Local hydraulic conductivity may vary greatly due to the heterogeneous distribution of the physical properties of the aquifer. Groundwater flow in the SRPA is to the south-southwest at rates between 1.5 to 20 feet per day. Near NRF, natural recharge to the SRPA occurs by infiltration from the Big Lost River, Little Lost River and Birch Creek, and to a lesser extent by infiltration due to precipitation. The average annual precipitation at the INEEL is approximately 8.8 inches. Anthropogenic recharge sources include the NRF sewage lagoons, the Industrial Waste Ditch (IWD), and historical site leaching beds/pits; these recharge sources are relatively small in comparison to natural sources.

NRF is located in the central portion of the INEEL. The land surface at NRF is relatively flat, with elevations ranging from 4,840 feet towards the far end of the NRF IWD, which is located approximately 200 yards north of NRF, to 4,870 feet at the south side of NRF. NRF is not located in the 100-year flood plain, although parts of the INEEL are on the flood plain. A flood with a recurrence interval in excess of 10,000 years is capable of inundating NRF (Ostenaa, 1998, 1999). This number assumes that the diversion dam located approximately 8 miles southwest of NRF is intact. Without the diversion dam, the flood recurrence interval capable of inundating NRF shrinks to possibly 5,000 to 8,000 years. Recurrence Interval refers to how often a flood of a given magnitude is likely to occur.

NRF is located on the Big Lost River alluvial plain and is approximately 1.5 miles from the closest portion of the Big Lost River. The thickness of alluvial sediment near NRF ranges from several inches to in excess of 60 feet north of NRF. Near surface sediments at NRF consist of alluvial deposits of the Big Lost River and are composed of unconsolidated fluvial deposits of silt, sand, and pebble-sized gravel. Most of the soil near NRF is mapped as sandy loam or loess. The loess is an accumulation of wind deposited silt-sized particles.

A complex sequence of basalt flows and sedimentary interbeds underlie NRF. The sedimentary interbeds vary in thickness and lateral extent and separate the basalt flows that underlie the surficial alluvium. Samples from basalt flows have been correlated into 23 flow groups that erupted from related source areas. Known eruption vents occur to the southwest, along what is referred to as the Arco volcanic rift zone, to the southeast along the axial volcanic zone, and to the north at Atomic Energy Commission Butte. The uneven alluvial thickness and undulating basalt surface at NRF are typical of basalt flow morphology.

The SRPA occurs approximately 375 feet below NRF, and consists of a series of saturated basalt flows and interlayered pyroclastic and sedimentary material. Drinking water for employees at NRF comes from several production wells located in the central portion of the facility. Perched water, which lies above the regional water table approximately 100 feet below land surface, occurs in several locations at NRF including beneath the IWD, the sewage lagoons, and historically the leaching beds/pits. In general, perched water forms at any location where a substantial surface recharge is present. The most significant perched water at NRF is located beneath the outfall of the NRF industrial waste ditch. Figure 2 shows the suspected locations of current and historical perched water zones.

The following sections discuss various aspects of the NRF site physical geology. These sections are summaries and are discussed in more detail in Appendix A of this document. Appendix A contains a hydrogeological report covering NRF data from 1972 to 1999.

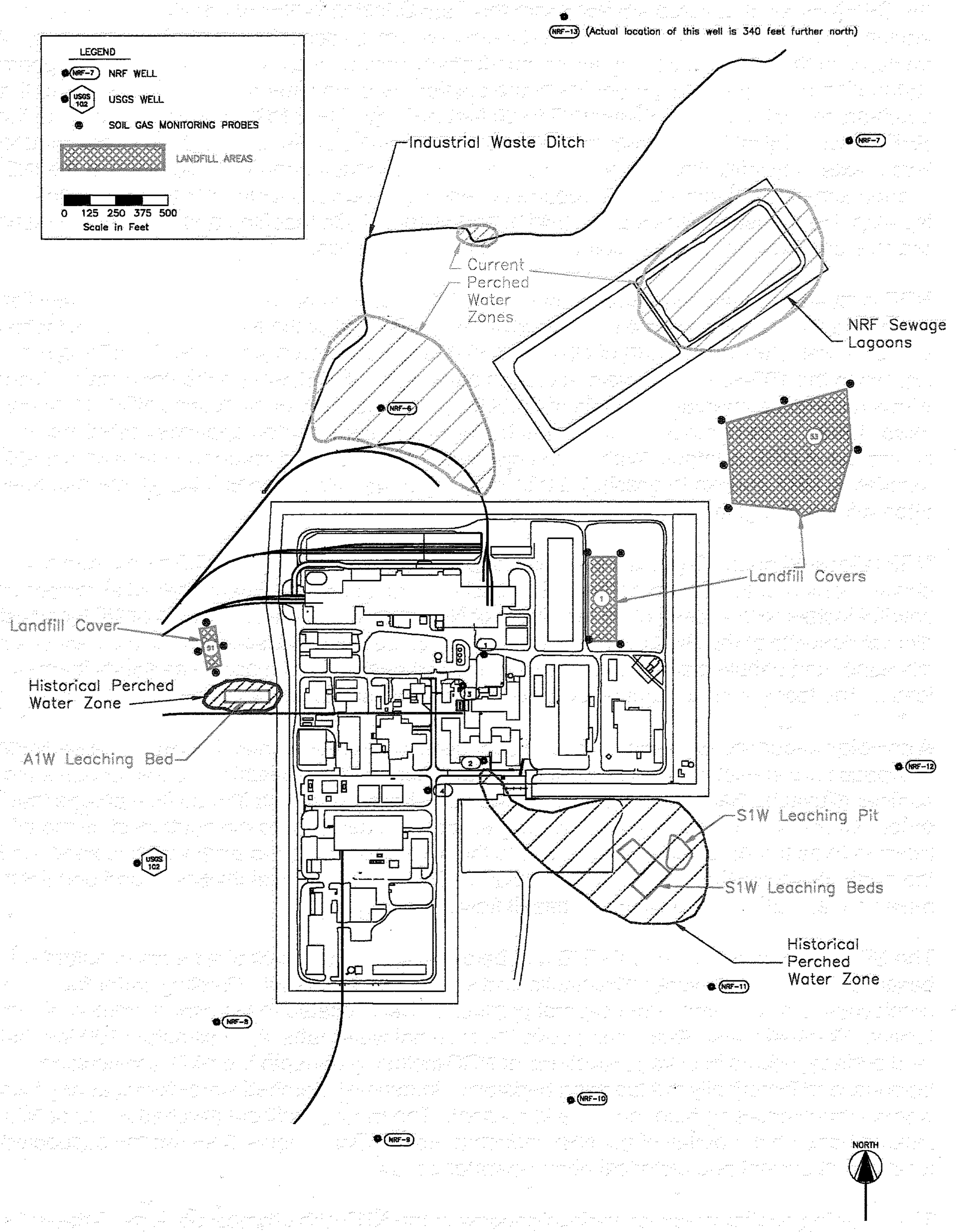

Figure 2 Suspected Location of Current and Historical Perched Water Zones at NRF

3.2.2 Geology of the Snake River Plain

The Snake River Plain (SRP) can be described as a bow shaped plain that stretches from Ashton, Idaho at its northeastern edge to Ontario, Oregon at its western edge. Elevation of the plain varies from approximately 6500 feet near Ashton to approximately 1600 feet west of Boise. Rocks of basaltic composition are prominent at the surface over the entire SRP, thus it is often mistakenly considered to be one region or unit possessing a common structure and origin. From a geological perspective, the SRP can be separated into two or three distinctive regions.

Some researchers (Maybe, 1982), divide the SRP into a western segment, a central segment, and an eastern segment based on the geophysical characteristics of the plain. Other researchers (Leeman, 1982, Alt and Hyndman, 1989) note that the SRP can be divided into two segments based on lithostratigraphic and fault geometry. NRF is located in the eastern portion of the SRP. The eastern and central SRP are not fault bounded. The lithology of the eastern and central SRP are best described lithostratigraphically as a thin veneer of basalt overlying a very thick sequence of rhyolite. Both the rhyolite and basalt sequences are occasionally interlayered with sedimentary deposits. A lithologic log of a well near NRF shows that 2200 feet of interbedded basalt and sediments overlie at least 8200 feet of welded tuffs, tuffaceous sands, nonwelded ash-flow tuff, air-fall tuff, and rhyodacite ashflow. This log is typical of the central and eastern SRP (WRIR 86-4020).

3.2.3 Geomorphology

NRF is located on a fluvial plain, the origin of which is attributed to historical deposition of the Big Lost River. Flooding is very unlikely, since NRF is not within the current 100-year flood plain, but NRF is located within the historical flood plain of the Big Lost River. Sediments deposited by the Big Lost River consist of interbedded sand, gravel, silt, and clay that in places are in excess of sixty feet thick. The sand, gravel, and silt of the alluvial plain were deposited historically during a period of time that possessed a climate that was considerably wetter than the climate of today. At present, the plain is experiencing a period of non-deposition. The fluvial plain surrounding NRF is oriented generally north-south, and is bounded on the east by basalt outcrops. These outcrops rise to a maximum of approximately 30 feet above the adjacent fluvial plain. Northwest of NRF, an arcuate-shaped ridge is present at the surface. Best seen from aerial photographs, this feature is reported to be a series of extinct eruption vents (EG&G, 1988). These vents begin several miles west of NRF, but are not visible at the surface at NRF. Low lying, highly or moderately weathered basalt flows rising between 10 and 30 feet above the fluvial plain are located approximately 1/2 mile west of NRF. Beyond these low lying hills is the Lost River Mountain Range. These mountains rise to an elevation in excess of 9000 feet.

Aerial photographs taken of the area surrounding NRF show a mosaic of abandoned or dry meandering channels. Several prominent features are evident in these photographs, including a number of point bar deposits and abandoned oxbows. A major abandoned meander channel is located approximately 600 feet due west of the IWD. This channel is 12 feet across and 6 to 8 feet deep. At the surface, abandoned meander channels are present in varying states of erosion. The regional surface surrounding NRF gently dips to the north, and ranges in elevation from 4870 feet south of NRF to 4830 feet north of NRF. The elevation within the NRF security fence ranges from 4852 feet to 4848 feet above sea level. Several man-made irrigation canals cross the desert terrain near NRF. The most prominent of these canals lies approximately 1/4-mile north-northwest of NRF. This canal is 20 feet wide and 15 feet deep. It rises above the desert floor 8 to 10 feet. Water no longer flows in these channels and canals, and they do not appreciably influence the hydrogeology of the IWD. These features would effect the hydrology of NRF only during an extreme flood event associated with the Big Lost River; however, the relatively large distance of NRF from the Big Lost reduces the possibility of flooding.

3.2.4 Structural Geology

The eastern SRP lies within the Basin and Range physiographic province, but within itself exhibits few characteristics typical of the basin and range spreading. The general appearance of the plain suggests that it was formed from rifting oriented along a northeast/southwest trending axis. This would result in the apparent lateral separation of the northwest-southeast trending normal fault mountains which are located on either side of the SRP. In actuality, rifting is occurring, but the orientation is along a northwest-southeast trending axis. Several prominent rift features embedded in the Snake River Plain are observable on high altitude reconnaissance maps of the eastern SRP. These features are believed to be extensions of the normal faults that bound the ranges located to the north and south of the plain.

A combination of the North American continent moving westward, and a rifting center located near the eastern edge of the Great Basin, has caused a stretching of the crust. This stretching is exhibited in the form of down dropped valleys and raised mountains in most of the Great Basin. In the SRP, this stretching is accommodated by plastic flow and infilling with basalt (Alt and Hyndman, 1989; Mabey, 1982; Leeman, 1982).

3.2.5 Lithostratigraphy

The following four sections discuss the important lithologic features associated with the lithostratigraphy beneath NRF. The four features include the near surface alluvium, the boundary between the near surface alluvium and the basalt, interbeds contained within the basalt, and the basalt itself. Much of what is known about these lithologic features is derived from the numerous boreholes and wells which have been drilled at NRF over the past 50 years.

3.2.5.1 Near Surface Alluvium

There are two types of surficial sedimentary deposits typically found at NRF. The topsoils are primarily loess deposits believed to be of wind-blown origin. Analysis of the loess shows that its primary constituent is the clay montmorillonite with secondary constituents of illite, quartz, feldspar, and carbonates (Chen-Northern Report, 1991). Montmorillonite is a swelling clay and possesses a high cation exchange capacity (Deer et. al, 1978, p. 250). The presence or absence of loess, and its thickness, are important factors in predicting contaminant migration. The thickness of the loess near NRF varies from several inches to over ten feet (EG&G Report, 1988, Phase I Closure Plan and Sample Collection Report, WEC, 1988). In some isolated locations near NRF, winnowing has caused fine grain sand dune deposits to form. In most places near NRF, the loess and sand deposits overlie gravel deposits of fluvial origin.

NRF is located near the western edge of a fluvial (meander) plain. This plain is several miles wide and consists of well rounded to sub-angular, moderately to poorly sorted sand and gravel interbedded with silt and clay. Much of the sand and gravel is stratified, which is evidence of its fluvial origin. Most of the gravel clasts consist of a wide variety of rock types, the source of which are the mountains located north and west of NRF, and include sedimentary, metamorphic, and igneous (plutonic) rocks. Individual clasts range in size from three quarters of an inch to two inches in diameter. Some of the clasts are composed of basalt derived from the basalt flows that surround the fluvial plain. The shape of individual gravel clasts is indicative of distance of transport and resistance to abrasion. Clay and fine silt interbeds are found sporadically throughout the fluvium, but are commonly found at the basalt/fluvium interface. These clay interbeds usually possess lower permeability than the surrounding sand and gravel. Past geologic investigations have demonstrated that the formation of perched water is facilitated by infilling of fractures in the top of the basalt with clay (Cecil et. al, 1991).

The alluvial gravels of the Big Lost River either directly overlie a thin soil/clay layer immediately overlying the basalt or a widespread clay and silt deposit interpreted to be of fluvial or lacustrine origin (F/L deposit). The contact between the alluvium and clay and silt deposit has been described as abrupt to gradational. In areas where alluvium was observed to overlay basalt, the contact was often marked by an increase in the percentage of basalt clasts imbedded within a one to two foot layer of soil located directly above the basalt bedrock. These soils ranged from white to light brown in color and are interpreted to be a buried soil horizon that developed prior to the deposition of the fluvium. The F/L deposit is coarser grained and darker in color than the soil covering the bedrock. The F/L deposit was determined to be present wherever the elevation of the top of the basalt was below approximately 4825 feet above sea level (asl).

The F/L deposit is characterized by light brown silty clay interbedded with fine sand and occasional gravels. These layers occur as repetitive fining upward sequences that range in thickness from four inches to one foot. Near the contact with the underlying basalt, these fining units are occasionally interlayered with basaltic gravels. Percolating water that originates from surface discharge sources or precipitation appears to be inhibited by the clay content of this unit.

3.2.5.2 Top of Basalt

Over the past 35 years, a number of boreholes have been drilled near NRF which have penetrated to the top of the basalt. These data were used to construct a map of the top of the basalt. It is important to understand how the surface of the basalt changes laterally because of evidence that shows that this surface can impede the downward migration of water. Because of this impedance, perched water has been found accumulating at this interface. If the surface that causes the perched water to form is tilted, then the perched water will flow in the down dip direction. Any contaminants that may be present in the water will be carried along with the water to locations that may be remote from their origin. This phenomenon has the potential of creating phantom contamination. That is, the occurrence of contamination for which no apparent source exists.

3.2.5.3 Interbeds - Occurrence and Distribution

Sedimentary interbeds separate many of the basalt flows that occur beneath NRF. These interbeds vary in composition, thickness, and areal extent. Four major interbeds have been identified in the subsurface. The first important interbed is brick red to red-orange in color and occurs at a depth that varies from 70 to 120 feet. This interbed is widespread and ranges in thickness from less than six inches to over 14 feet. The sediments in this interbed are classified as a lithic wacke and are composed of poorly sorted mixtures of angular to subangular sand sized clasts. The term lithic wacke was used by Chen Northern to describe specimens of immature sandstone with high clay content and a large number of rock fragments other than quartz and chert (Chen Northern, 1991, and Blatt et. al., Origin of Sedimentary Rocks). Dominant grain fragments are lithic basalt and quartz, with the finer constituents consisting of silt and clay. The sediments of this interbed appear to be loosely consolidated in the subsurface. Perched water has been associated with this interbed, although it is not known for certain whether the interbed itself, or a tight basalt located immediately beneath, is the perching layer. Because of its wide-ranging occurrence, and physical properties, this interbed has the potential for being an impedance to contaminant migration.

Interbeds at 105 feet, 205 feet, 267 feet, and 370 feet have been identified from geophysical logs from many wells near NRF. Several minor interbeds are also present. The interbeds are laterally discontinuous in these wells.

3.2.5.4 Basalt

Underlying the alluvium is approximately 1500 to 2000 feet of transitional olivine to alkaline olivine basalts. Minerals present in this section include magnesium olivine, clinopyroxene, calcic plagioclase, spinel, and magnetite (Chen-Northern, 1991). Depth from the surface to the top of the basalt surface ranges from zero to 60 feet, but is typically 30 feet. The basalt consists of individual flows ranging in thickness from 5 feet to over 70 feet. Basalt that is void of interconnected vesicles and fractures is nearly impermeable. The hydraulic conductivity measurements from basalt cores collected from a borehole located just north of the NRF site are generally in the range of 1×10^{-8} cm/sec (Chen Northern, 1991). However, local fracturing greatly increases effective conductivity values. Extremely variable transmissivity values are common at NRF as is evidenced by values from NRF-2 and NRF-7, which are located approximately 1200 feet apart. Measured transmissivity in these wells were 3.1 ft^2/day in well NRF-7 and 576,000 ft^2/day in NRF-2.

Based on evidence observed from cores collected at NRF, it appears that most of the fractures in the basalt are probably the result of the cooling process. If this is so, these fractures will be confined to one flow, and will not transect other flows. The balance of the fractures could be the result of regional or local stresses, although not enough data is available at this time to confirm this hypothesis. These fractures appear to be randomly distributed in the horizontal plane, but are concentrated at the top of individual flows in the vertical plane. Some flows are completely fracture free, while other flows are fractured from top to bottom. No evidence exits to substantiate the conclusion that one set of fractures is continuous from the surface to the aquifer (i.e., providing an uninterrupted pathway for potential contaminants to follow). There is evidence that indicates that some portions of the basalt, perhaps occurring in quasi-linear trends, are more highly fractured than the surrounding basalt. An increase in the frequency of fractures in the basalt would expedite surface water infiltration into the aquifer. It would be improper to assume that these 'fracture zones' act as conduits, allowing surface water to flow unimpeded from the surface directly to the aquifer. Water that may infiltrate along these hypothetical trends would interact with surface soils, clay-lined fractures, and the soils contained in interbeds. In areas where these trends are present, however, travel time in the basalt would tend to decrease.

3.3 Climate and Hydrogeology

3.3.1 Climate

The water table elevation in the SRPA is sensitive to precipitation and temperature at the INEEL and the surrounding watershed basin. Since only a small percentage of direct precipitation actually infiltrates into the subsurface, the main source of recharge to the SRPA at the INEEL is from the Big Lost River, Little Lost River, and Birch Creek drainage systems. Climate affects runoff to these drainages which in turn affect hydrogeology at NRF; therefore, a good knowledge of the climate at or near the INEEL is essential to understanding water table

hydrology at NRF. Climatological data has been collected at the INEEL Central Facilities Area (CFA) since the early 1950s. CFA is located approximately 7 miles south of NRF, so climate data at this location only approximates conditions at NRF; however, similar physiographic characteristics between the two facilities make the use of these data feasible.
The following is a summary of an analysis of climatic data pertinent to NRF hydrogeology. A more detailed examination of these data is presented in Appendix A, Section 2.1.

Several ephemeral lakes known as playas are located directly north of NRF. These playas are situated at the lowest elevation of a closed basin. Water enters this basin in four ways: by direct flow from the Big and Little Lost Rivers and Birch Creek, and by precipitation falling directly on the playas. Climate directly affects the amount of water entering the playas via the four pathways. When more water enters the basin than leaves, a lake forms and begins to expand outward. Water infiltrates through the bottom of the playas and recharges the aquifer below. The playas are hydrologically upgradient to NRF; therefore, the water table at NRF is affected when water reaches the playas for an extended period. Factors that enhance water movement to the playas are extensive snow pack in conjunction with rapid melting, and periods of high precipitation coupled with low to moderate evaporation rates. Temperature directly influences these factors.

3.3.1.1 Temperature

Temperature enhances subsurface recharge by several mechanisms. First, lower wintertime temperatures coupled with higher precipitation results in a deeper snow pack. Second, lower temperatures freeze the soil, promoting runoff when the snow melts. The longer the ground is frozen, the less water infiltrates into the ground in the upland regions. Third, less sublimation occurs with lower temperatures. Conversely, more evapotranspiration occurs with higher temperatures. The analysis in this document relies heavily on average temperature. On a daily basis, this term means the average of the high and low temperature for the day being considered. Average temperature, in reference to summer or winter, indicates the average of the average daily temperatures for the months of June, July, and August, or December, January, and February, respectively.

Since 1972, the hottest summer occurred in 1988 with an average temperature of 68.7 degrees Fahrenheit (°F). The coldest winter occurred during 1984-85 (December, January, and February) with an average temperature of 7.9 °F. The coolest summer occurred in 1993 with an average temperature of 58.6 °F. Finally, the warmest winter occurred in 1980-81 with an average temperature of 25.5 °F. Table 2 summarizes these data. The following dates are hydrologically significant. 1980-81, the year of the warmest winter, was near the beginning of the resumption of flow in the Big Lost River channel. Flow continued in the channel almost constantly for the next five years. 1985, the year of the coldest winter, marks the beginning of the current warming trend and the beginning of a seven year drought. The year 1988, which coincides with the hottest summer, marks what is probably the height of the seven year drought, and 1993, the year of the coolest summer, is considered the end of the drought.

Analysis of temperature data reveals that the average temperature appears to have risen approximately 3 °F from 1972 to the present; however, since 1992, the average yearly temperature near NRF has been falling. The decade of the nineties has on average been warmer than the previous 20 years. Seven of the past ten winters, including five of the past six, have been warmer than average. Over the past 28 years, the average summer-time temperature was 64.4 °F and the average wintertime temperature was 18.9 °F. The average wintertime temperature for the past five years was 21.8 °F. Furthermore, warmer summers have been alternating with cooler summers over the past 8 or 9 years. Warmer summers occurred in 1992, 1994, 1996, and 1998, and cooler summers in 1993, 1995, 1997 and 1999.

If the average wintertime temperature is plotted since 1972, three separate warming trends are revealed. The first occurred between 1972 and 1981, the second between 1985 and 1992, and the last between 1993 and the present. Each warming period was followed by an abrupt decline in temperature. From 1972 to present the average winter temperature has risen approximately 4 °F.

The plot of average summer-time temperatures reveals a strong warming trend of approximately 4 °F between 1972 and 1992 as well. Since 1992 the data can be interpreted as either a sharp cooling period followed by the beginning of a second warming period, or a continuation of the long-term warming trend. Regardless of cause, the last five years have been unusually moderate.

The data described above indicates that a long term climatic change may be occurring at the INEEL. The duration and significance of the change is yet to be determined.

3.3.1.2 Precipitation

Over the past 28 years, the meteorological station at CFA at the INEEL has received an average of 8.77 inches of precipitation per year. An analysis of monthly and yearly precipitation at CFA since 1972 also shows several trends. These data demonstrate the cyclical nature of precipitation over the past 28 years. This pattern persists even in the monthly data. The average precipitation per month is 0.72 inches with an associated standard deviation of 0.6 inches. Occasional monthly precipitation spikes that exceed 1.32 inches (mean + standard deviation) occur.

The amount of precipitation in inches received each year can vary from year to year. For example, in 1988, the precipitation for the year was 5.41 inches, or approximately 3 inches below average. The total precipitation in 1995 was 13.38 inches, or approximately 5 inches above average. Between 1988 and the present, annual precipitation has on average been increasing. Unlike the wet period that occurred between 1980 and 1986, a period that exemplifies a steady rise in yearly precipitation totals, the more recent wet cycle has been erratic. Beginning in 1988, and lasting until 1997, yearly precipitation totals alternated from lower to higher to lower again in relation to average precipitation. Each alternating year's precipitation averaged higher than two years before. This trend does not appear to continue after 1997. This alternating pattern correlates well with the higher summertime temperatures discussed above. Again, this appears to be evidence of a changing climatic pattern.

3.3.1.3 Conclusions

The data presented in this section show that the climate at the INEEL is highly variable. In a space of 28 years, noticeable differences in maximum and minimum precipitation and average temperature have occurred. Table 2 summarizes these extremes. Over the past 28 years, cyclic variations in temperature and precipitation have occurred. Cyclic variations are more prominent in precipitation data and average wintertime temperature data than average summertime data. Although the average summertime temperature has been creeping higher, the temperature has remained relatively stable from year to year. This is in contrast with average wintertime temperatures that vary from year to year. These data indicate that the climate at the INEEL has gone through subtle but noticeable changes over the last 28 years. Most notably, the nineties have been more moderate in temperature, and wetter than the previous two decades. Furthermore, precipitation events have become more erratic, where the likelihood of a major precipitation event seems to have increased. Overall, temperatures appear to be on the rise as well as moderating year to year variations. If current patterns continue (which is always an uncertainty), the future climate at the INEEL may produce more rain, promote more infiltration (thinner frost layers), and promote continued water flow into the sinks north of NRF. The resulting rise in water table level may have an effect on contaminant migration and groundwater flow paths at NRF. Furthermore, these climate changes may subject NRF to greater risk of flooding from high intensity precipitation events.

Table 2 Climatic Variation Summary 1972 to 1999 (Degrees Fahrenheit)

	Summertime Temp	Wintertime Temp	Precipitation
Maximum Average	68.7	25.5	13.38
Minimum Average	58.6	7.9	5.41
Difference in Averages	10.1	17.6	7.97

3.3.2 Water Table Elevations

Water table elevation data for all active groundwater monitoring wells were collected and organized into hydrographs. An analysis of these graphs was performed. A summary of the conclusions of this analysis follows. A more detailed examination of these data is presented in Appendix A. Hydrographs from wells USGS-12, 97, 98, and 99 were constructed using data collected from these wells since 1976. NRF wells 6 and 7 reflect water table changes since their construction in 1991. Apart from a few minor differences, the shape of these hydrographs is very similar. The major difference between hydrographs is in the timing of peaks and troughs.

The long-term hydrographs produced from water elevation data show two troughs and one peak. The first trough stretches from 1979 to the first part of 1983, and the second trough occurs between 1993 and 1996. The minimum water table elevations observed in the second trough in the hydrographs were lower than those observed in the first trough. This represents a continuation of a long term trend of declining water table elevation observed in other INEEL wells (Pittman et.al., 1988). For example, the hydrograph constructed from USGS-99 (NRF's most downgradient well) data shows that the difference between the minimum water table elevation in the two troughs was approximately 5.5 feet. The difference between maximum and minimum water table elevations in this well range between 16 and 20 feet (See Appendix A, page 35 for more details). Both troughs correspond to extended drought periods that occurred during the late 1970s and between 1986 and 1993. All the hydrographs also contained one peak that occurred between 1986 and 1988. The peak followed an extended period that received above-normal precipitation. Currently, the INEEL is experiencing another dryer than normal period. The rebounding of the water table witnessed in the hydrographs is moderating, and has peaked in USGS-12.

Water flux through a particular well and the corresponding water elevation can change rapidly. For example, during a period of just over two years (1984 to 1986), the water elevation in USGS-12 rose 9.38 feet. Similarly, during a period of 42 days (spring, 1985), the water elevation in this well rose 1.79 feet, or approximately one-half inch per day. Finally, in a space of approximately one year (1988 to 1989), the water table elevation fell 4.29 feet. Well USGS-12 is the NRF groundwater monitoring well nearest to the Lost River sinks. However, wells located approximately 5 miles downgradient of USGS-12 show similar rapid changes in water table elevations. Such rapid water level changes may cause sudden shifts in groundwater flow patterns around NRF; therefore, great care should be taken when interpreting the results from local monitoring wells, and when estimating aquifer flow paths.

Near NRF, flow to the Lost River sinks results in large quantities of water recharging the SRPA. The resulting mound beneath the sinks eventually reaches the NRF groundwater monitoring wells and is exhibited as a rise in water table elevation. Because the flow to the sinks is intermittent, water table elevations will rise and fall. The time it takes for peaks and troughs to pass through the NRF groundwater monitoring wells is a function of aquifer hydraulic properties and the quantity of water reaching the aquifer.

The travel time for peaks (and troughs) to pass from USGS-12 to USGS-99 is estimated to be between 101 to 282 days, as determined by comparing the hydrograph of USGS-12, the most upgradient NRF groundwater monitoring well, to the hydrograph of USGS-99, the most downgradient NRF groundwater monitoring well. USGS-12 and USGS-99 are located approximately 5 miles apart. Based on these numbers, water appears to travel with a velocity between 94 and 261 feet per day. This velocity is many times greater than published estimates from INEEL sources that range from 5 to 20 feet per day (Robertson, 1974). Based on Robertson's velocity range, the travel time from USGS-12 to USGS-98 should be between 3.6 to 14.5 years, not the 101 to 282 days estimated above. Additional research may be necessary to more accurately estimate flow rates near NRF, which affects local hydrology and contaminant transport.

3.4 Land Use and Resource

3.4.1 Past and Current Land Use

The INEEL was established in 1949 as the National Reactor Testing Station by the United States Atomic Energy Commission as a site for building, testing, and operating nuclear reactors, fuel processing plants, and support facilities with maximum safety and isolation. In 1974, the area was designated as the Idaho National Engineering Laboratory to reflect the broad scope of engineering activities conducted there. The name was changed to the INEEL in 1997 to reflect the redirection of its mission to include environmental research.

The U.S. Government occupied portions of the INEEL prior to its establishment as the National Reactor Testing Station. During World War II, the U.S. Navy used about 270 mi^2 of the site as a gunnery range. The U.S. Army Air Corps once used an area southwest of the Naval gunnery area as an aerial gunnery range. The present INEEL site includes all of the former military areas and a large adjacent area withdrawn from the public domain for use by the DOE. The former Navy administration shop, warehouse, and housing area are presently the Central Facilities Area of the INEEL.

The Bureau of Land Management manages the surrounding areas for multipurpose use. The developed area within the INEEL is surrounded by a 500 mi^2 buffer zone used for cattle and sheep grazing. Communities nearest to the INEEL are Atomic City (south), Arco (west), Butte City (west), Howe (northwest), Mud Lake (northeast), and Terreton (northeast). In the counties surrounding the INEEL, approximately 45% is agricultural land, 45% is open land, and 10% is urban. Sheep, cattle, hogs, poultry, and dairy products are produced; and potatoes, sugar beets, wheat, barley, oats, forage, and seed crops are cultivated. The U.S. Government or private individuals own most of the land surrounding the INEEL.

Fences and security personnel strictly control public access to facilities at the INEEL. State Highways 22, 28, and 33 cross the northeastern portion of the INEEL and U.S. Highways 20 and 26 cross the southern portion. A total of 90 miles of paved highways pass through the INEEL and are used by the public.

NRF consists of three former Naval nuclear reactor prototype plants, the Expended Core Facility (ECF), and miscellaneous support buildings. Construction of the Submarine Thermal Reactor prototype (S1W) at NRF began in 1951. The prototype completed operation in 1989. The Large Ship Reactor Prototype (A1W) was constructed in 1958 and completed operation in January 1994. The submarine reactor plant prototype (S5G) was constructed in 1965 and completed operation in May 1995. The prototypes were used to train sailors for the nuclear Navy and were used for research and development purposes. The Expended Core Facility, which receives, inspects, and conducts research on Naval nuclear fuel, was constructed in 1958 and is still in operation.

3.4.2 Projected Land Uses

NRF is projected to continue operations at ECF until at least 2035. Operations will continue to include receiving, inspecting, and conducting research on Naval nuclear fuel, as well as the temporary dry storage of Naval nuclear fuel until a permanent national repository is available. Construction of a dry storage facility is currently underway. The purpose of this facility is to store expended Naval nuclear fuel in a non-aqueous environment. It is scheduled for completion in 2001. Other NRF operations will include the decontamination and dispositioning actions associated with retired buildings and facilities.

3.4.3 Groundwater Use

3.4.3.1 Past Use

NRF has been in operation since the early 1950s. Up through the mid-1990s, the site was primarily used for training Navy personnel to operate nuclear propulsion plants aboard Naval vessels. Well NRF-1, drilled in 1950, supplied early demand for water at NRF. Water from this well was used for drinking, irrigation, sewerage, and cooling the S1W prototype plant. As the number of plants increased so did the number of Navy students and full time employees. The demand for water also increased. Additional water wells were constructed in 1951 (NRF-2), 1956 (NRF-3) and 1964 (NRF-4). During its peak period in the mid-1980s, NRF had three operating prototypes (S1W, S5G, and A1W), the Expended Core Facility (ECF), and approximately 3300 full-time, part-time, and Naval personnel. At this time, peak water demand was approximately 300,000,000 gallons per year. Most groundwater used at NRF eventually is returned to the environment in one of several ways. NRF water is discharged to the Industrial Waste Ditch (IWD) or to the Sewage Lagoons (SL) where it evaporates, transpirates, or infiltrates into the subsurface. The balance of the water was used to irrigate lawns or was supplied to cooling towers for cooling operating reactors. The ultimate fate of the water for irrigation is the same as for water discharged to the IWD and SL; water from the cooling towers was mostly lost through evaporation, but occasional flushing of the tower disposed of some water to the IWD where its fate was as described above.

3.4.3.2 Present Use

In 1989, the S1W prototype was shut down. The A1W plant was shut down in 1994, followed by the shutdown of the S5G plant in 1995. Navy students are no longer trained at NRF. Currently, ECF is the only facility at NRF still operating. Beginning in 1989, groundwater use at NRF has been declining, particularly since 1996. Current water use at NRF is approximately 100,000,000 gallons per year. This use is primarily limited to domestic consumption, irrigation, and ECF operation. The environmental fate for groundwater is the same as described above except that cooling tower evaporation is no longer occurring.

3.4.3.3 Future Use

In the near future, water usage at NRF is expected to remain stable. However, as environmental remediation and inactivation projects end, the total number of people including subcontractors at NRF is expected to decline. This decline will lead to a proportionate drop in water usage.

3.5 History of Contamination

3.5.1 Summary of Site History

The landfill areas that are the subject of the 5-year review are designated in the INEEL Federal Facility Agreement and Consent Order (FFA/CO) Action Plan as 8-05-1 (Field Area North of S1W), 8-05-51 (West Refuse Pit #4), and 8-06-53 (East Refuse Pit and Trenching Area). All are abandoned refuse disposal areas or landfills, and all were capped with an engineered soil cover with gas monitoring wells placed around them. These three sites are discussed below.

3.5.2 Landfill History

NRF operations during the time frame when the landfills were active consisted of Naval ship reactor prototype facilities and support operations (i.e., cooling systems operations; water treatment operations; laboratory operations; production support operations from paint, electrical, machine, and equipment maintenance shops; and subcontractor construction support operations). The characteristics of the refuse disposed of in the three landfills was influenced by the NRF facilities and the various support operations. The typical waste disposal practice at the sites was to dump refuse in the trenches, incinerate the combustible refuse, and then bury the residual. When these sites were abandoned, the remains were left in place and covered with soil from the surrounding area.

The resulting primary contaminant source at all three landfill areas is refuse material and refuse degradation products buried at the sites. From records kept since 1971 of wastes sent from NRF to the CFA landfill, it is estimated that almost two-thirds of the waste would have consisted of office trash. Less than 1% of the waste would have consisted of solid and liquid chemicals, waste oil, and solvents (WEC 1994).

In addition, during the operational period of these landfills, major construction activities were carried out. These construction activities included the construction of two prototype plants and other support buildings (i.e., training facilities, storage buildings, etc.). These construction activities would have contributed a considerable amount of construction debris to these landfills, therefore decreasing the estimated hazard (i.e., reduced percentage of chemicals).

8-05-1 is located inside the NRF perimeter fence, north of the S1W prototype plant. 8-05-51 is located to the west of NRF, outside of the NRF perimeter fence. 8-06-53 is located to the northeast of NRF, outside of the NRF perimeter fence and adjacent to the northern NRF sewage lagoon. Figure 3 shows the location of the landfills.

3.5.2.1 8-05-1 History

Utilization of 8-05-1 started in approximately 1951 and continued until 1960. The locations of the primary disposal areas within 8-05-1 were identified from old drawings, photographs, verbal testimony, and records. Site 8-05-1 covers an area of 192,500 sq. ft. (350 ft wide and 550 ft long). Within this area, there was a previously utilized trench containing buried waste and a mounded area consisting of surface debris and soil. The buried waste disposal trench is located on the west side of the site. The depth of this trench ranges from approximately 4 ft on the north end to 25 ft on the south end. The dimensions of this trench are 120 ft wide and 375 ft long. Prior to the placement of the final landfill cover, the trench was originally covered by an interim soil cover (approximately three feet thick). The cover constructed to contain only the buried wastes in the trenches encompasses an area of approximately 56,000 square feet. From historical records, photographs, and drawings, the bulk of the waste was deposited on the southern half of the site where the trench dimensions were greater. In addition, the north end of the trench was covered when Spray Pond #2 was constructed around 1954 (WEC 1995), thus limiting the amount of wastes that were deposited in the north end of the trench.

3.5.2.2 8-05-51 History

8-05-51 started operating in about 1957 and continued until 1963. From a preliminary investigation, the shape of this unit has been determined to be irregular with curved boundaries. The overall size of the site was originally estimated to be approximately 450 ft long, varying in width from 100 to 175 ft. Based on photographs and a magnetometer survey of the location, only one disposal trench was identified. The trench was originally estimated to be approximately 250 feet in length, 15 to 20 feet wide, and 10 to 15 feet in depth (WEC 1992). The length and width of the trench were further refined by the magnetometer survey and determined to be 175 feet and 40 feet, respectively (WEC 1995). The cover constructed to contain only the buried wastes in the trenches encompasses an area of approximately 15,000 square feet. Inspection of photographs indicated the materials disposed of at this location tended to be related more to construction debris than the wastes found in the other two units. Also it was noted that there were no drums in the trench at the time the photographs were taken. It is believed that a portion of this site was previously used as a construction staging area.

3.5.2.3 8-06-53 History

8-06-53 was used as a disposal area from about 1956 to 1970. The various types of waste which may have been disposed of in this area include waste petroleum products, small quantities of waste paints and solvents, construction debris, scrap metal, and cafeteria waste. Geophysical data indicates that there were at least five pits or trenches at 8-06-53. From the geophysical data and verbal testimony, the trenches were estimated to have been up to 90 feet wide by 7 to 10 feet deep and up to 350 feet long. The area of site 8-06-53 that included both surface debris and the trenches was approximately 400,000 square feet. The cover constructed to contain only the buried wastes in the trenches encompasses an area of approximately 281,000 square feet.

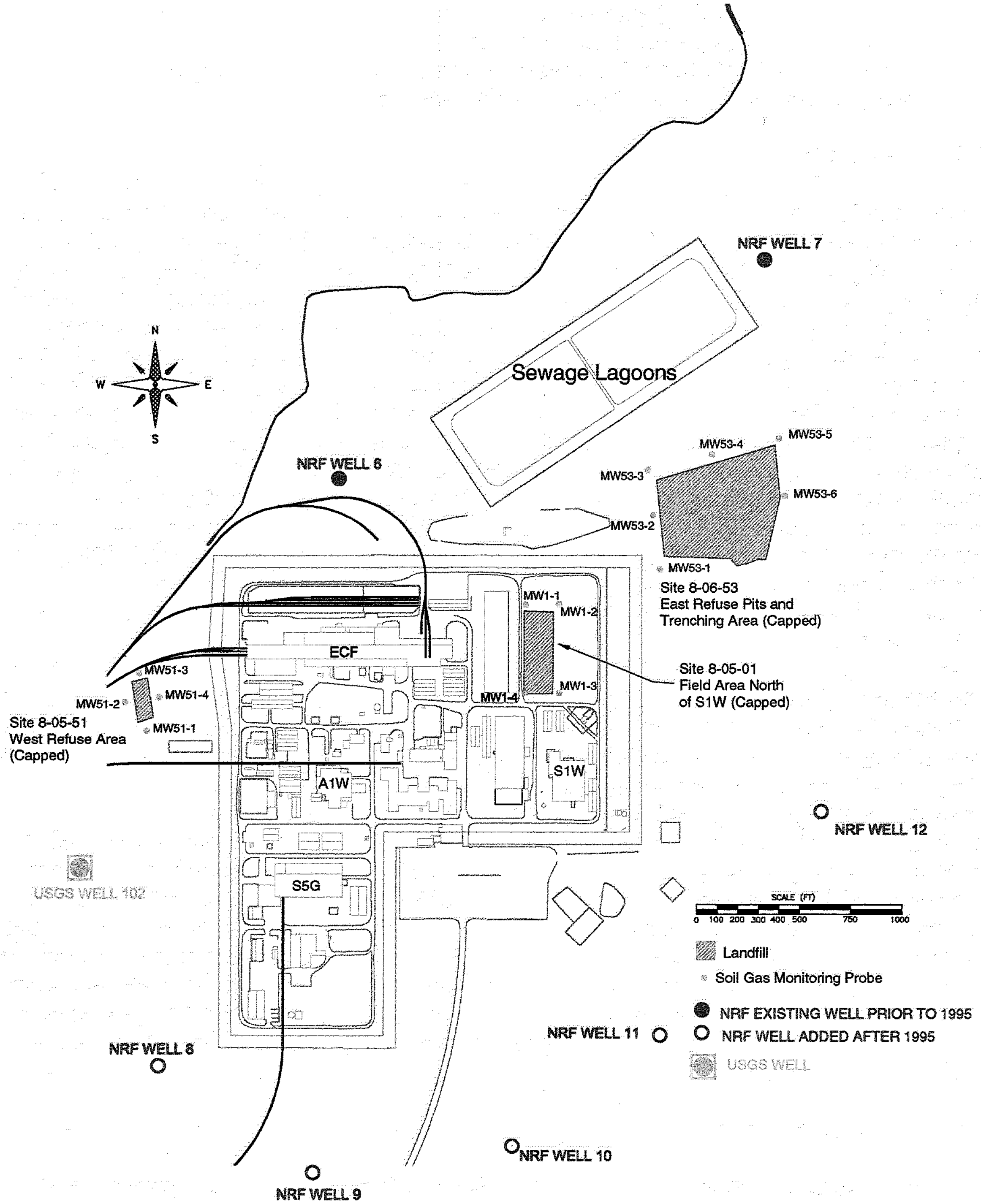

Figure 3 Location of NRF Landfill Areas and Groundwater Monitoring Wells

3.5.3 Groundwater Monitoring History

3.5.3.1 Monitoring Summary

NRF has routinely collected groundwater monitoring data since 1989. Prior to this time, no formalized groundwater monitoring program existed. Until 1996, this monitoring was conducted on a voluntary basis. Since 1996, monitoring has been conducted to comply with agreements between the EPA, IDHW, and DOE, Office of Naval Reactors. These agreements were the result of findings associated with two Remedial Investigation and Feasibility Studies (RI/FSs) and numerous Track 1 and Track 2 studies, all conducted under the CERCLA process. During 1989, NRF organized its groundwater monitoring network mostly using existing wells. The network consisted of NRF wells 1, 2, 3, 4 (water supply wells for NRF); United States Geological Survey (USGS) wells 12, 15, 17, 97, 98, 99 and 102; and INEL Water Supply Well #1. The reliability of some of the data collected from these wells was considered moderate to low since these wells, with the exception of USGS-102, were not specifically designed to support monitoring of the upper portion of the aquifer. This is the portion of the aquifer most likely to contain contaminants released from NRF. In 1991, two wells built by NRF (NRF-6 and 7) were added to the monitoring network. These wells, as all wells added subsequently by NRF, are designed to monitor the upper 50 feet of the aquifer. In 1996, NRF added six new wells to the monitoring network (NRF-8 through 13). Furthermore, NRF wells 1 through 4, USGS wells 15 and 17, and INEL Water Supply Well #1 were removed from the network. Figure 1 of Appendix A shows the current configuration of the NRF groundwater monitoring network.

As an aid in analyzing groundwater data collected at NRF, the NRF monitoring wells have been divided into four groups. These groups are called: Regional Upgradient Wells (USGS-12 and NRF-7); Effluent System Monitoring Wells (NRF-6 and NRF-13); Site Downgradient Wells (NRF-8 through NRF-12 and USGS-102); and Regional Downgradient Wells (USGS-97 through USGS-99). Each monitoring group is designed to monitor a specific portion of the aquifer surrounding NRF. The Regional Upgradient Wells monitor water which is supposed to be unaffected by NRF activity. However, water in these wells may be affected by other INEEL activities or farming. The Effluent System Monitoring Wells are designed to monitor waters affected by the NRF Industrial Waste Ditch (IWD) and the NRF sewage lagoons. The Site Downgradient Wells were placed to specifically monitor the impact that ongoing operations at NRF are having on the Snake River Plain Aquifer (SRPA) beneath NRF. The IWD and sewage lagoons are considered again as possible sources of groundwater contamination. Finally, the Regional Downgradient wells are placed downgradient of NRF to be a secondary measure of the effects that NRF is having on the SRPA, and to provide data to compare to Regional Upgradient data.

Currently NRF analyzes groundwater samples for 29 inorganic constituents, nutrients, and generic organic indicators, 5 radionuclides or their indicators, and 26 volatile and semi-volatile organic constituents. Table 3 lists the groundwater constituents that are monitored, and the analytical method, Maximum Contaminant Level (MCL), and Maximum Contaminant Level Goal (MCLG) associated with each contaminant.

Table 3 Groundwater Monitoring Constituents			
Constituent	Analytical Method	MCL (mg/L)	MCLG (mg/L)
Aluminum	6010A ICP	0.2	*
Antimony	6020 ICP/MS	0.006	0.006
Arsenic	6020 ICP/MS	0.05	*
Barium	6020 ICP/MS	2	2
Beryllium	6020 ICP/MS	0.004	0.004
Cadmium	6020 ICP/MS	0.005	0.005
Calcium	6010 ICP	*	*
Chromium	6020 ICP/MS	0.1	0.1
Copper	6020 ICP/MS	1.3	1.3
Iron	6010A ICP	0.3	*
Lead	6020 ICP/MS	0.015	0
Magnesium	6010A ICP	*	*
Manganese	6020 ICP/MS	0.005	*
Mercury	7476A	0.002	0.002
Nickel	6020 ICP/MS	0.1	0.1
Potassium	6010 ICP	*	*
Selenium	6020 ICP/MS	0.05	0.05
Silver	6020 ICP/MS	0.1	*
Sodium	6010A ICP	*	*
Thallium	6020 ICP/MS	0.002	0.0005
Zinc	6020 ICP/MS	5	*
Sulfate	300	250	*
Chloride	300	250	*
Nitrate (as N)	353.2	10	10
Nitrite (as N)	354.1	1	*
Total Kjeldahl Nitrogen (TKN)	351.2	*	*
Phosphorus	365.3	*	*
Total Organic Carbon (TOC)	415.1	*	*
Total Organic Halogens (TOX)	9020B	*	*
Gross Alpha (as Thorium 230)	EPA 900	1.5 pCi/L	*
Gross Beta (as Cesium 137)	EPA 900	5 pCi/L	*
Strontium-90	EPA 905	8 pCi/l	*
Tritium	R-1173-76	20,000 pCi/L	*
Quantitative Isotopic Gamma	EPA 901.1	*	*
Benzene	524.2	0.005	0
Carbon Tetrachloride	524.2	0.005	0
1,1-Dichloroethane	524.2	*	*
1,2-Dichloroethane	524.2	0.005	0
1,1-Dichloroethylene	524.2	0.007	0.007
Cis-1,2-Dichloroethylene	524.2	0.07	0.07
Trans-1,2-Dichloroethylene	524.2	0.1	0.1
Ethylbenzene	524.2	0.7	0.7
Methylene Chloride	524.2	0.005	0

Table 3 Groundwater Monitoring Constituents (continued) Constituent	Analytical Method	MCL (mg/L)	MCLG (mg/L)
1,1,2,2-Tetrachloroethane	524.2	*	*
Tetrachloroethylene	524.2	0.005	0
Toluene	524.2	1	1
1,1,1-Trichloroethane	524.2	0.2	0.2
Trichloroethylene	524.2	0.005	0
Trichlorofluoromethane	524.2	*	*
Vinyl Chloride	524.2	0.002	0
Xylenes (total = o+p+m)	524.2	10	10
Benzo(b)fluoranthene	525.1	*	*
Benzo(a)pyrene	525.1	0.0002	0
Di-n-butylphthalate	525.1	*	*
Di(2-ethylhexyl)phthalate	525.1	0.006	0
Di-n-octylphthalate	525.1	*	*
Isophorone	525.1	*	*
Naphthalene	525.1	*	*
Phenanthrene	525.1	*	*
Pyrene	525.1	*	*

*No MCL or MCLG has been set for this constituent

Groundwater quality can be affected by many different factors such as the composition of the rocks in the recharge source area, composition of the rocks in the aquifer, climatic conditions, time of year, and anthropogenic activity. The task of measuring these factors is very difficult; therefore, an element of uncertainty will be present in any hydrogeological investigation that is conducted. In this light, the body of evidence needed to prove or disprove a hydrogeological hypothesis is often unavailable for direct examination. The investigator is then left with indirect or circumstantial evidence, to infer conclusions. Determining true groundwater quality is a task of hydrogeology that is both difficult and achievable. The proper interpretation of these data requires a full understanding of the geologic processes at work at NRF specifically, and at the INEEL generally. Hydrogeologic and geologic data are useful as a predictor of other potential environmental impacts at NRF. The following sections discuss the data from NRF and surrounding areas in more detail.

3.6 Summary of Contaminants of Concern at NRF

3.6.1 Soil Contaminants

During the initial stages of the Track 2 Investigations for the three landfill areas, NRF and the agencies agreed that sampling of the buried waste would not be performed, since sampling and analysis of buried waste in landfills is usually not a viable means of characterizing the source term due to the extreme heterogeneity of solid waste disposal sites. Therefore, only limited sampling was conducted during the Track 2 Investigations to address specific exposure pathways for the risk assessment (WEC 1993 and 1994).

In addition to sample data collected during the Track 2 Investigation, the records from 1971 through 1988 were used to characterize the source term. These records as documented in the

INEEL Industrial Waste Management and Information System, include an inventory of the wastes sent from NRF to the CFA Landfill or other approved off-site hazardous waste disposal facilities, and are considered representative of the types of wastes in the NRF landfills. These records were used since no official NRF record was kept during operation of the landfills. Thus, the more recent retrievable INEEL records provided a reasonable estimate of the type, and a conservative estimate of the quantity, of wastes generated at NRF from 1951 to 1970, when the three landfills were active. As a result of the data collection and evaluation process for the three designated landfill areas, several chemicals of potential concern were identified. The Track 2 Investigation sample data and historical records evaluation indicated that three waste types were of potential interest: waste oil, solvents, and chemicals. For waste oils and solvents, the compounds of primary concern are volatile organic compounds.

Additional compounds of primary concern for waste oils and fuel oil are polynuclear aromatic hydrocarbons (PAHs). However, the waste was typically burned after disposal and there may only be a residual amount remaining. Since the remedial action for the landfills included the presumptive remedy for landfills, which requires groundwater monitoring and preventing contact with the landfill contents, the source term for waste oil and fuel oil was not further investigated under the Track 2 Investigations (WEC 1994). Based upon a review of historical records of the waste stream during the Track 2 Investigation, several inorganic compounds were found to be representative of NRF solid waste. These compounds were identified as potassium chromate, silver nitrate, and mercuric nitrate.

The specific volatile organic compounds that were initially identified as chemicals of potential concern in the Track 2 Investigation are xylenes, ethylbenzene, 1,1,1-trichloroethane (TCA), and tetrachloroethylene (PCE). The specific metals that were identified in the Track 2 Investigation are chromium, mercury, and silver.

As previously stated, the Chemicals of Potential Concern identified as a result of the data collection and evaluation process during the Track 2 Investigation included several volatile organics and metals. Even though xylenes, ethylbenzene, TCA, and PCE were initially the only organic compounds identified as chemicals of potential concern in the Track 2 Investigation, other volatile organic compounds were detected in several of the soil gas samples at all three of the landfill areas. The additional volatile organic compounds detected during the Track 2 Investigations included: trichlorofluoromethane (Freon 11), 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), chloroform, and trichloroethylene (TCE). Freon 11 was detected at all three landfill areas at low concentrations (1 to10 ppb on a volumetric basis (v/v), or 5.6-56 $\mu g/m^3$). Freon 113 was detected at two landfill areas (Sites 8-05-1 and 8-06-53) in three samples at low concentrations (2.3-5.3 ppb v/v or 17.6-40.5 $\mu g/m^3$). Chloroform was detected at only one landfill area (Site 8-06-53) at low concentrations (1.0-19 ppb v/v or 4.9-92.6 $\mu g/m^3$). TCE was detected at only one landfill area (Site 8-06-53) at low concentrations (at a maximum concentration of 16 ppb v/v or 85.8 $\mu g/m^3$); however, TCE was also detected in the field blanks (at a concentration of 7.9 ppb v/v or 42.4 $\mu g/m^3$). Initially, these compounds were not considered chemicals of potential concern because of the low levels detected and because the analytical results for some of these compounds were not conclusive. However, analytical results from sampling conducted under the current monitoring program (subsequent to landfill capping, and included as part of the Operations and Maintenance (O&M) Plan), reveal that these organic compounds have been positively detected at low levels.

Xylenes and ethylbenzene were identified initially as chemicals of potential concern at sites 8-05-1 and 8-05-51. However, during the Track 2 Investigation for Site 8-06-53, detection of xylenes and ethylbenzene were attributed to the sample collection, handling, and/or analysis process and not the result of site conditions (WEC 1994). Xylenes and ethylbenzene have been detected occasionally under the current monitoring program included as part of the O&M Plan; however, these constituents have been associated with occasional contamination problems during the sample collection process.

Based upon historical records of waste streams at NRF, chromium, mercury, and silver were originally identified as contaminants of potential concern in buried waste at all three landfill areas, during the Track 2 Investigation. During the Track 2 Investigation, annual disposal of chromium, silver, and mercury into NRF landfills was calculated along with the estimated total quantity of these three metals disposed of in the landfills.

3.6.2 Groundwater Contaminants

Groundwater at NRF contains both natural and anthropogenic constituents. Naturally occurring groundwater constituents are determined by the chemical properties of the rocks located in the source area, and the chemical properties of the rocks located along the groundwater flow path. At NRF, man-caused contamination in groundwater (outside the Naval Reactors program) is primarily limited to upgradient agricultural activities, with nitrates being the main contaminant of concern. The Little Lost River system is the primary source of recharge to the Snake River Plain Aquifer (SRPA) north of NRF. Contaminants that could be carried by the Little Lost River could potentially affect water that eventually flows beneath NRF. Other potential contaminants include phosphates, herbicides, and pesticides. A secondary source of potential man-caused contamination of groundwater at NRF is related to the Big Lost River. Any constituent that can reach the waters of the Big Lost River could flow downstream and affect the aquifer near NRF. These potential contaminants include those described for the Little Lost River, but also include contaminants related to the operation of other INEEL sites. To date, no significant levels of contaminants have been identified in upgradient groundwater.

Through the course of NRF's operation, some chemicals and radionuclides have been released to the environment, either accidentally or intentionally in accordance with practices acceptable at the time. Many of the same constituents are present as contaminants in groundwater. The IWD RI/FS Work Plan and the NRF Comprehensive RI/FS provided lists of potential contaminants released at NRF. Not all of the constituents have been observed in the groundwater. Several reasons for this include limited source, low migration potential, dilution or degradation through various natural processes, and very conservative estimates on the quantity of the constituents released. The following constituents have been observed in groundwater at NRF in concentrations above local background levels: aluminum, arsenic, copper, mercury, nickel, selenium, iron, chromium, barium, lead, zinc, calcium, potassium, magnesium, sodium, chloride, sulfate, nitrite plus nitrate, total organic halogens (TOX), phosphorus, and total organic carbon (TOC). Small quantities of chloroform, naphthalene, tetrachloroethylene, and 1,1,1-trichloroethane have also been detected. The background concentration for these organic compounds is near zero. Radioactivity in groundwater also exceeds local background concentrations for tritium, cesium-137, gross alpha, and gross beta; however, these constituents are significantly below their respective Federal or State regulatory level.

3.6.3 Risk Assessment

3.6.3.1 Potential Targets

The potential receptor populations at risk identified under the Track 2 Investigation included current occupational (site workers), future residents, and future recreational users of the area.

3.6.3.2 Results of Risk Assessments

The exposure pathways identified for the risk assessment conducted during the Track 2 Investigation included the ingestion of contaminated soil, the ingestion of groundwater, the inhalation of volatile compounds, and the inhalation of fugitive dust.

Exposure concentrations for the chemicals of potential concern identified in the Landfill Areas Track 2 Investigation for the risk assessment were as follows:

Contaminant	8-05-1	8-05-51	8-06-53
Metals (mg/kg)			
Chromium	0.38	NA	5.7
Mercury	0.09	0.65	0.11
Silver	0.50	NA	0.61
Organics ($\mu g/m^3$)			
Tetrachloroethylene	NA	NA	2,572
1,1,1-Trichloroethane	NA	NA	2,300
Ethylbenzene	1,000	NA	NA
Xylenes	9,950	1,000	NA

Because non-intrusive sampling, for the most part, was utilized for the landfill areas, the soil concentrations used to perform risk assessments had a high degree of uncertainty. The soil concentrations for chromium, mercury, and silver at these sites were estimated and compared to risk-based soil concentrations to evaluate the groundwater pathway. The estimated soil concentrations for these specific metals used for this comparison were calculated from the mass estimated for each of the metals suspected to have been disposed of at each of the landfill areas. The concentrations were calculated by dividing the mass of each metal by the mass of the source volume.

The exposure concentrations used for the organic constituents detected in the soil gas survey were the mean and maximum concentrations. The use of the maximum concentration permitted placing an upper bound on exposure. The use of the mean concentration, a less conservative approach, provided a more realistic exposure concentration.

The chemical intake was calculated in accordance with the Track 2 guidance (DOE 1995) with the exception of the inhalation of volatiles pathway. The formulas for calculating the chemical intake for the inhalation of volatiles pathway requires a concentration of the volatile compound in the soil. The soil gas survey analysis does not permit the calculation of the concentration in the soil. Therefore, the calculations for the inhalation of volatile pathway involved the calculation of the contaminant-specific air concentration (Appendix E in both WEC, 1993 and WEC, 1994) and the contaminated area that contributes to vapor emissions.

The Hazard Index (HI) determined for mercury, 1,1,1-trichloroethane, ethylbenzene, and xylenes for each applicable pathway for the occupational, residential, and recreational scenarios were well below the target of 1.

The increased cancer risk (ICR) resulting from the presence of tetrachloroethylene in soil gas was found to be less than the target of 1E-6.

A comparison of the estimated soil concentration of chromium with risk-based concentration (where the HI=1 and ICR=1E-6) revealed that estimated chromium soil concentrations at the source were at least one order of magnitude less than the risk-based concentrations with the exception of the soil concentration for hexavalent chromium via the ingestion of groundwater pathway. However, sampling and analysis at the INEEL indicates that the hexavalent chromium that was disposed of in the past has been reduced and is currently present as trivalent chromium, which presents a much reduced risk to human health. Chromium at NRF is expected to have been similarly reduced.

3.6.3.3 Determination of Primary Health Threat

The risk analysis presented above indicates that the concentrations of the identified chemicals of potential concern do not appear to pose an unacceptable risk to the receptors. However, the uncertainty associated with the identification of organic chemicals of potential concern for the landfill areas is considered high. In addition, non-intrusive sampling, for the most part, was utilized for the landfill areas. Therefore, the soil concentrations used to perform risk assessments had a high degree of uncertainty. Since the presumptive remedy for the landfills was going to be used at these inactive landfill areas (which would require monitoring, restrict access, and prevent contact with landfill contents), the source characterization of additional chemicals of concern was not investigated. Some assumptions made during the Track 2 Investigations included a 50% reduction in waste volume during incineration, and that contamination of metals was equally distributed throughout the landfill mass.

Thus far, the monitoring data from both groundwater and soil gas samples have not revealed any significant change in risk to potential receptors as determined in the Track 2 Investigations, nor have any regulatory limits been exceeded.

4.0 Remedial Actions

4.1 Remedy Selection

A Feasibility Study (FS) was performed on the landfill areas (WEC, 1994). The FS was a comprehensive evaluation of potential remedial action alternatives for OU 8-05 and 8-06 landfills that represent units 8-05-1, 8-05-51, and 8-06-53. The presumptive remedy for CERCLA municipal landfills as given in the EPA directive 9355.0-049FS, "Presumptive Remedy for CERCLA Municipal Landfill Sites," was used for these landfill units, since they were similar in nature and content to municipal landfills and the EPA directive expects the presumptive remedy to be used at all appropriate sites. Using the presumptive remedy eliminated the need for the initial identification and screening of alternatives during the FS.

4.1.1. Remedial Action Objectives

The Remedial Action Objectives (RAOs) for the landfill areas were developed in accordance with the RI/FS CERCLA Landfill Guidance (EPA 1991). The RAOs specified the contaminants and media of interest, exposure pathways, and preliminary remediation goals, to support development of a range of source containment alternatives. The attainability of the RAOs to protect human health and the environment was addressed through the detailed evaluation of each remedial action alternative. Compliance with potential chemical-specific applicable or relevant and appropriate requirements (ARARs) was one method used to evaluate the extent to which each remedial action alternative would meet the RAOs.

The RAOs for the environmental media of groundwater, soil, and surface water for the landfills were identified as follows:

- **Groundwater**

  For Human Health and Environmental Protection

  Ensure that the Snake River Plain Aquifer downgradient of NRF has no contaminant levels above Maximum Contaminant Levels (MCLs) due to migration of contaminants from the landfills.

  Minimize infiltration and resulting contaminant leaching to the Snake River Plain Aquifer.

  Meet all ARARs.

- **Soil/sediment**

  For Human Health

  Assessed risk; non carcinogenic hazard quotient and carcinogen risk level as determined by Qualitative Risk Assessment are acceptable for current receptors considering conservative nature of the calculations. However, since the landfill contents were not sampled and characterized it was not possible to accurately assess the risk for future receptors and, therefore, intrusion into the landfill contents must be restricted.

Prevent direct contact with landfill contents.

Meet all ARARs.

For Environmental Protection

Meet all ARARs.

- **Surface Water**

For Human Health and Environmental Protection

Control surface water runoff and erosion of landfill cover.

Meet all ARARs.

4.1.2 Remedial Actions

The following remedial actions were considered: 1) No Action, 2) Containment with Native Soil Cover, and 3) Containment with Single Barrier Cover. The Containment with Native Soil Cover was the selected remedy.

The selected remedy involved the containment of landfill contents by covering with a native soil cover. This cover also provides a barrier against direct contact of the landfill contents by the potential receptors and reduces the potential for migration of contaminants from the identified landfill areas by reducing infiltration of surface water. There are four components of this alternative: capping each landfill area; monitoring; performing O&M on each soil cover; and obtaining a deed restriction. (1) The landfill areas would be capped using conventional construction equipment to ensure a native soil cap at least 24 inches thick covers the entire landfill area. The soil cover would be graded and natural vegetation planted to stabilize the soil surface, promote evapotranspiration, and decrease erosion of the soil cover. (2) Soil gas monitoring would be performed to assess the effectiveness of the cover, and groundwater monitoring would be performed to assess these areas and other areas at NRF. (3) Periodic inspections and maintenance would be performed to ensure the integrity of the landfill cover. (4) A deed restriction would be obtained for each area, including an additional 50 feet beyond each landfill boundary to protect the integrity of the cover. This would limit the sale and use of the property. The area would be surveyed and signs would be installed to warn of the presence of landfill and potentially contaminated soils. Since the site is currently an active DOE facility, such a deed restriction is postponed pending any future release of the site for commercial or residential use.

4.2 Remedy Implementation

Once the remedies were determined, the actual implementation of the remedies began. Remedy implementation included the design criteria, which is a discussion of the design logic that went into executing a given remedy. It also included a discussion of construction costs, since a given remedy must be cost-effective if it is to be viable. Finally, remedy implementation included an as-built discussion of the project. Each of these topics is discussed below for the landfill covers, the groundwater monitoring well network, and for the soil gas monitoring probe network.

4.2.1 Landfill Covers

4.2.1.1 Design Criteria

The regulatory requirements regarding final closure of landfills provide for the placement of a final cover designed and constructed to:

- Have a permeability (where permeability is expressed as hydraulic conductivity with units of cm/sec) less than or equal to the natural subsoils of the surrounding area,
- Function with minimal maintenance,
- Promote drainage and minimize erosion,
- Accommodate settling and subsidence to maintain integrity of the cover, and
- Minimize the migration of liquids.

The design criteria for the landfill cover included the selection of appropriate soils that minimize erosion with properties (i.e., permeability) that will also limit infiltration. The cover design incorporated an appropriate slope that provides adequate drainage of surface runoff. To further minimize erosion and the migration of liquids through the landfill, the landfill cover included a top vegetative layer. To minimize settling and subsidence, the surfaces of the landfill areas were preloaded with fill material, compacted, and leveled to the same elevation as the surrounding natural surfaces, which provided a stable base for the cover. The landfill cover was then placed over top of each of the landfill areas, moderately compacted (except the upper foot of top soil), completed with a proper surface slope, and seeded. To minimize maintenance of the vegetative cover, indigenous plants were used.

4.2.1.2 Construction Cost

The estimated total cost for the remedial action activities for the NRF inactive landfill areas as presented in the ROD was $2,004,800. This included the cost for construction of the landfill covers, construction and sampling of the groundwater monitoring wells and soil gas monitoring probes, as well as maintenance costs for all. The estimated cost in the ROD for only the construction phase of the landfill covers, wells and probes was $1,613,800. The estimated total construction costs were revised to $1,993,544 during the remedial design phase. The actual total construction cost for the remedial action activities performed at the NRF landfill areas was $1,775,780. The actual cost for the construction of the landfill covers and soil gas probes (not including the cost of constructing the groundwater monitoring wells) was $1,139,535.

4.2.1.3 As Built Discussion

Landfill cover construction operations are summarized below. The construction activities included: (1) site clearing, (2) landfill unit base layer fill and grading, (3) subsurface soil cover construction, (4) topsoil cover construction, and (5) vegetative cover. The specifications for the landfill cover material (Type A, Type B, and Type C) were given in the Remedial Design Report/Remedial Action Work Plan (RD/RAWP). Type A material was used to form a sound base for the landfill cover to minimize or eliminate subsidence. The subsurface cover layer was constructed with Type C material for the purpose of minimizing water infiltration to the waste. The topsoil cover layer was constructed with Type B material designed to support native vegetation, inhibit erosion, and provide a 3-5% top slope to promote drainage. The landfill cover design was modified to minimize steep side slopes, thereby minimizing erosion in those areas. Based on the revised design, the landfill areas required some shallow excavating around the periphery, and the surface soils required stripping and surface contouring to allow for the cover to be "keyed" into the existing grade. Since these soils were potentially suitable as Type B Top Soil, samples were collected from 8-05-51 and 8-06-53 to verify the suitability of this soil as Type B material.

Since the subsurface cover layer was to be constructed for the purpose of minimizing water infiltration to the waste, an appropriate hydraulic conductivity/permeability range for the Type C soil (cover material for the subsurface layer) had to be derived. The appropriate hydraulic conductivity range was determined from soil sample results. Since the average permeability of the soil layer beneath the waste was deemed more appropriate with consideration to the spatial distribution of the soils beneath the landfill, and due to concerns with desiccation cracking with soils having a hydraulic conductivity of 10^{-7} cm/sec, the agencies established a hydraulic conductivity/permeability range between 10^{-5} to 10^{-6} cm/sec for the Type C soil.

4.2.1.3.1 Site Clearing

Site clearing activities were performed to remove vegetation greater than 3 inches in diameter and surface debris, and to provide scarification of the landfill base to facilitate blending of newly placed soil layers. Cleared soils that were sufficiently free of debris were stockpiled adjacent to each landfill for use as the top soil cover (Type B), since these soils contained organic matter beneficial to re-establishing the vegetative cover.

Sites 8-05-51 and 8-06-53 are located outside the fenced NRF areas and had a vegetative cover consisting of mostly sage brush and grass. Site clearing operations for Units 8-05-51 and 8-06-53 were achieved using a motor grader to remove the vegetation. Large (>3 in.) debris was removed from the immediate surface.

Site 8-05-1 is located within the fenced NRF area and had sparse areas with insignificant vegetation. However, this site included a large surplus of material (estimated to be 20,000 yd^3) stockpiled on the landfill area. This material included construction debris (i.e., concrete, asphalt, re-bar), rocks, metal, and other materials that did not meet the specifications for Type A, Type B, or Type C cover materials. This material was removed, segregated and screened per INEEL Landfill disposal requirements, and disposed of at the INEEL Landfill.

4.2.1.3.2 Base Layer

A motor grader, bulldozers, water truck, and smooth drum roller and/or sheep's foot roller were used to knock down, process, and compact Type A fill material into place for the landfill cover base at each of the landfill areas. Each of the three landfill units was filled, compacted, and graded as necessary to achieve a 3 - 5% gradient. As-built drawings of each of the landfills showing the final base grade are provided in Appendix B (Landfill Cover Drawings designated as bottom of subsurface soil). Placed soils were compacted to achieve 90% of the maximum density for Type A soil per the RD/RAWP.

4.2.1.3.3 Subsurface Soil Cover

Each of the three landfill units was filled and graded using Type C soil for the subsurface cover layer to achieve a minimum 3 foot cover at Site 8-05-1 and a minimum two foot cover at Sites 8-05-51 and 8-06-53 with a 3 - 5% gradient. As-built drawings of each of the landfills showing the Type C soil cover grade for the subsurface layer are provided in Appendix B (Landfill Cover

Drawing for each location). Engineered soils were compacted to achieve 90% of the maximum density for Type C soil in accordance with the requirements described in the RD/RAWP.

4.2.1.3.4 Top Layer

Each of the three landfill units was filled and graded using Type B soil to achieve a minimum 1 foot final top soil cover with a 3 - 5% gradient. Soil for the topsoil cover was loosely placed with minimum compaction for establishing proper vegetation density. The final topsoil cover thickness at Sites 8-05-51 and 8-06-53 was 1 foot. The final topsoil cover thickness at Site 8-05-1 averaged 1.5 feet. As-built drawings of each of the landfills showing the top soil cover grade or finish grade are provided in Appendix B (Landfill Cover Drawing designated as finish grade).

4.2.1.3.5 Vegetative Cover

The vegetative cover consisted of indigenous vegetation with the characteristics specified in the RD/RAWP. The specific plant mixtures selected were also recommended for use as appropriate vegetative cover for erosion control based on studies at other INEEL sites (WEC 1995).

Mulching, seeding, and fertilization were performed in accordance with the RD/RAWP. Since the placement of the Type B soil layer was completed during the beginning of the summer, it was not an opportune time for seeding. Seeding and fertilization was postponed until late summer to provide a greater chance for plant growth in the spring. Mulch was applied in the interim following placement of the Type B soil to minimize erosion. Prior to application of the mulch, the soil surface was scarified using a spring-tooth harrow to loosen the soil and permit anchoring of the mulch. Straw mulch was applied and then anchored in the soil using a crimping disk.

Prior to seeding, fertilizer was applied at all three landfill areas. The fertilizer had a composition of 20% nitrogen and 48% phosphorus. The fertilizer was applied on the surface in the following approximate quantities: 75 pounds at Site 8-05-1, 30 pounds at Site 8-05-51, and 350 pounds at Site 8-06-53,. After the fertilization was complete, seeding was performed at all three landfill areas at the recommended seeding rates specified in the RD/RAWP for the three native plant species.

4.2.2 Groundwater Monitoring Network

4.2.2.1 Design Criteria

The design of the NRF Groundwater Monitoring Well Network was performed as three separate actions. The first action was to select existing wells, or design new individual wells to be incorporated into the Network. The second action was to place the wells at strategic locations and to create logical well groupings. The third action was to select the constituents to be monitored.

The NRF Groundwater Monitoring Network consists of individual wells designed and built over a period of 40 to 45 years. Some of these wells were built recently and were specifically designed to monitor the upper portion of the SRPA. Other existing wells, although designed to monitor the aquifer, were not designed to the higher quality standards now required. The selected wells were then administratively included into a network, with some wells being located upgradient and downgradient of NRF.

Constituent selection criteria were based partly on the list of chemicals known to have been released by NRF that could potentially contaminant the aquifer. During the first several years of operation of the monitoring network, this list included many of the constituents contained in Appendix IX of the Federal Drinking Water Standards. In 1996, this list was updated. Constituents that never appeared in NRF groundwater were removed from the analysis list, and new analytes were added.

The NRF Monitoring Network was designed and built in stages. As previously stated, the NRF Network was first brought on line in the fall of 1989. The original Network consisted of four NRF production wells, seven USGS wells, and a water supply well for a deep drilling project. In 1991, two new wells, NRF-6 and NRF-7, were constructed and added to the Network; these two wells were specially designed to monitor the upper 50 feet of the SRPA.

In 1994, the need to redesign the Groundwater Monitoring Network became apparent. Part of the need was in response to an INEEL wide "well fitness" survey. This survey identified problems with several of the NRF groundwater monitoring wells. In response, NRF modified the Network by removing the four NRF production wells, USGS 15 and 17, and INEL 1. At nearly the same time, six new wells were added. These wells, NRF-8 through 13, were designed as monitoring wells, targeting the upper 50 of the aquifer. Furthermore, a computer program called Monitoring Efficiency Model (MEMO) was used to design the placement of these wells. Since well placement design is so important, some technical aspects of the model are presented below. This presentation is taken from a more detailed description of the MEMO model in Section 4 of the Hydrogeological Study portion of the NRF Comprehensive RI/FS.

4.2.2.1.1 MEMO Model

MEMO is a contaminant transport model that provides a simple computerized method for optimizing monitoring well locations for groundwater monitoring networks at waste management areas. Input required for the model includes site geometry, hydrogeologic characteristics, and initial monitoring well locations. From these data, the program determines the efficiency of the monitoring network. The efficiency determination is based on whether a plume is detected by the monitoring well network before it crosses a specified buffer zone boundary. MEMO uses as input several parameters to which it is sensitive. These input parameters are dispersion, initial contaminant concentration, time, and nature of source area.

- Dispersion is the phenomenon by which a constituent in groundwater is mixed with uncontaminated water and becomes reduced in concentration Under ideal conditions (i.e., in an aquifer with completely uniform attributes), dispersion will cause contaminants to spread in the shape of an ellipse. The aquifer beneath NRF is highly fractured and possesses a wide range of hydraulic conductivity properties; therefore, contaminant plumes are often distorted and sometimes discontinuous.
- As the initial concentration of contaminant in the groundwater at the source increases, the downgradient width of the plume also increases.
- The expansion of a given contaminant plume decreases with time, and at a critical time the plume will stop growing in size.

- In general, a wider source area will produce a wider plume. Similarly, a continuous contaminant release will produce a larger plume than a one time release for a given initial contaminant concentration.

4.2.2.1.1.1 MEMO Modeling Work

Past studies show that the groundwater flow direction at NRF changes from a bearing of 165 degrees to 225 degrees over time; therefore optimal spacing between wells is variable. MEMO allows the user to model the efficiency of a given well network for various groundwater flow directions. The worst case flow direction for NRF is a bearing of 165 degrees, which maximizes the potential for contaminants to leave NRF undetected. Using a five well network (collectively called the Site Downgradient Wells), a flow direction of 165 degrees, and a C_D to C_O ratio of 0.025, 61.0% of the site is monitored. When a six well network using the same input parameter as above was modeled, the coverage increased to 96.6%. Finally, in an effort to improve the efficiency of the monitoring network, the wells were moved away from NRF 50 to 400 feet. Moving the wells further from NRF increased the monitoring efficiency by an average of 1.94% and ensures coverage for all sensitive areas. Figure 3 shows the location of Site downgradient monitoring wells.

The overall results of MEMO show that a monitoring network using five wells provides adequate coverage if large dispersivity values are assumed. However, for small, more conservative values, five wells are spaced too far apart and allow potential contaminants to leave NRF undetected. When groundwater flow is towards the southwest (225 degrees), several critical areas are not adequately monitored. As the locations of these five wells are adjusted to compensate for these inadequacies, other critical gaps are opened. Six wells provide adequate coverage for anticipated flow directions for the most conservative dispersivities, and near complete coverage is provided for larger values of dispersivity. Several critical gaps in monitoring coverage which appear using a six well array in close proximity to NRF are eliminated when the wells are moved further from the NRF site.

4.2.2.1.2 Constituent Analysis Design

Constituent analysis design at NRF has evolved over the past decade. In 1989, little was known of the geochemical characteristics of the water from the aquifer near NRF. In order to gather baseline information on water quality, a comprehensive suite of analyses were performed. The first round of samples looked for a wide variety of metals, nutrients, salts, organics, and radionuclides. These are the constituents described in CFR 40:261 Appendix IX plus radiochemistry. Originally, samples were collected on a bi-monthly basis. This was called Round 1 sampling. After several sampling intervals, the sampling frequency was decreased to quarterly and analytes were reduced to a select group of constituents. These included those found in CFR 40:265 Appendix III, CFR 40:265 Subpart F, and nickel, copper, zinc, and Base Neutral Acids (BNAs). This stage in NRF monitoring was called Round 2. Round 3 sampling included sample collection on a quarterly basis, and a list of analytes selected from the constituents included in the first two rounds.

During the 1994 to 1995 time interval, the list of analysis constituents was again modified. This modification was intended to align NRF with constituents of concern for the INEEL. In 1996, work on the landfill remedial action began. As part of the Record of Decision for the landfill areas, it was decided that the aquifer downgradient of the landfills would be monitored to determine whether these landfill areas have had any impact on the aquifer, and to allow for early detection of potential contaminants in the groundwater. The identification of analytes to be monitored focused on those that had been identified from the following: historical records, employee interviews, detection of the constituents in samples taken from monitoring wells and other site investigation sampling activities (i.e., soil and soil gas sampling), compounds that have been identified in process waste streams, potential degradation products, and those addressed in 40 CFR 141 considered as relevant and appropriate. Selection of target compounds for analysis was based on whether a compound is characteristic of the waste, easily and reliably detected analytically, and/or addressed by an applicable regulation to be monitored. The resulting list, which continues in use to the present, is provided in Table 3.

4.2.2.2 Construction Cost

The construction costs associated with the NRF Groundwater Monitoring Network are definable in terms of task. These tasks can be categorized as follows: 1) costs related to modification of existing wells; 2) costs related to the construction of new wells; and 3) costs related to the design and follow of the other two tasks. These tasks are discussed separately below.

1) During 1989 several wells were retrofitted with dedicated submersible pumps. Minor alterations were also required to lock the wells properly. The wells that were modified included USGS-12, 15, 17, 97, 98, and 99. Additionally, the NRF drinking water/production wells were modified with special fittings so that water samples could be easily taken. The costs for these modifications are shown in Table 4.

2) Three separate well construction events have occurred to date at NRF. The first well constructed was contracted through the USGS, and was given a USGS numerical designation, although funded by the Naval Reactors (NR) program. Construction of USGS-102 was completed in 1988. In 1991, NRF constructed two new wells near the IWD, NRF-6 and NRF-7. These wells were designed by NRF personnel, and constructed by contract using NR funds. Finally, in 1995, six additional groundwater monitoring wells were constructed, (NRF-8 through NRF-13). Again, NRF personnel using NR funds performed the design. The cost for the construction of these wells is shown in Table 4.

3) The final task involved establishment of the NRF Groundwater Monitoring Network, including design, follow, and administrative (DFA) costs.

Each of the three tasks had different amounts of DFA costs associated with them. These costs are estimated in Table 4.

4.2.2.3 As Built Discussion

All the wells constructed for the NRF groundwater network were designed to similar specifications. The goal was to create wells that were cost effective, that met or exceeded State and Federal guidelines, and that provided the data needed by NRF. The typical NRF well has a surface casing ranging from 12 to 22 inches in diameter. This surface casing terminates at the top of the first basalt encountered and is grouted in place. Most NRF wells are constructed with 10 inch diameter carbon steel casing from the first basalt to approximately 50 feet above the aquifer. In some wells, this casing is 12 inches in diameter. This casing is also grouted in place in such a manner as to prevent the grout from bridging and separating from the borehole wall. The casing in the NRF wells then telescopes down to a stainless steel 6-inch casing isolated from the carbon steel casing with dielectric insulating material. The bottom 50 feet of the casing consists of stainless steel screen. The screen is surrounded by gravel with the annular space at the top sealed with bentonite. All the casing is either welded or internally threaded. Each well is fitted with a submersible pump connected to a three-phase 5-horsepower motor. Water is pushed to the surface through a 1-1/2-inch stainless steel pipe. Figure 4 shows the major design elements of the NRF groundwater monitoring wells.

Table 4 Wells Construction Costs				
		Modifications	New Construction	DFA
USGS-12		$4,000	NA[1]	$1,000
USGS-15		$4,000	NA[1]	$1,000
USGS-17		$4,000	NA[1]	$1,000
USGS-97		$4,000	NA[1]	$1,000
USGS-98		$4,000	NA[1]	$1,000
USGS-99		$4,000	NA[1]	$1,000
USGS-102		NA	$75,000	$30,000
INEL-1		NA	NA[2]	NA
NRF-1		$1,000	NA[3]	$250
NRF-2		$1,000	NA[3]	$250
NRF-3		$1,000	NA[3]	$250
NRF-4		$1,000	NA[3]	$250
NRF-6		NA	$147,000	$25,000
NRF-7		NA	$147,000	$25,000
NRF-8		NA	$110,333	$24,000
NRF-9		NA	$110,333	$24,000
NRF-10		NA	$110,333	$24,000
NRF-11		NA	$110,333	$24,000
NRF-12		NA	$110,333	$24,000
NRF-13		NA	$110,333	$24,000
Total	**$1,289,998**	**$28,000.00**	**$1,030,998.00**	**$231,000.00**

NA[1] These wells were built prior to the development of the NRF Groundwater Monitoring Well Network. The decision to build these wells was independent of NRF actions.

NA[2] This well was constructed by other INEEL contractors as a water supply well for drilling a deep test borehole located south of NRF. No direct costs were incurred by NRF.

NA[3] These wells were built as water supply wells for NRF. Their construction costs were independent of the NRF Groundwater Monitoring Network Wells.

4.2.3 Soil Gas Monitoring Probes

4.2.3.1 Design Criteria

To assess the effectiveness of the three landfill covers in limiting water infiltration and soil gas emissions, soil gas monitoring (utilizing the soil gas emissions survey) was implemented at the cover and probe locations shown on Figure 3.

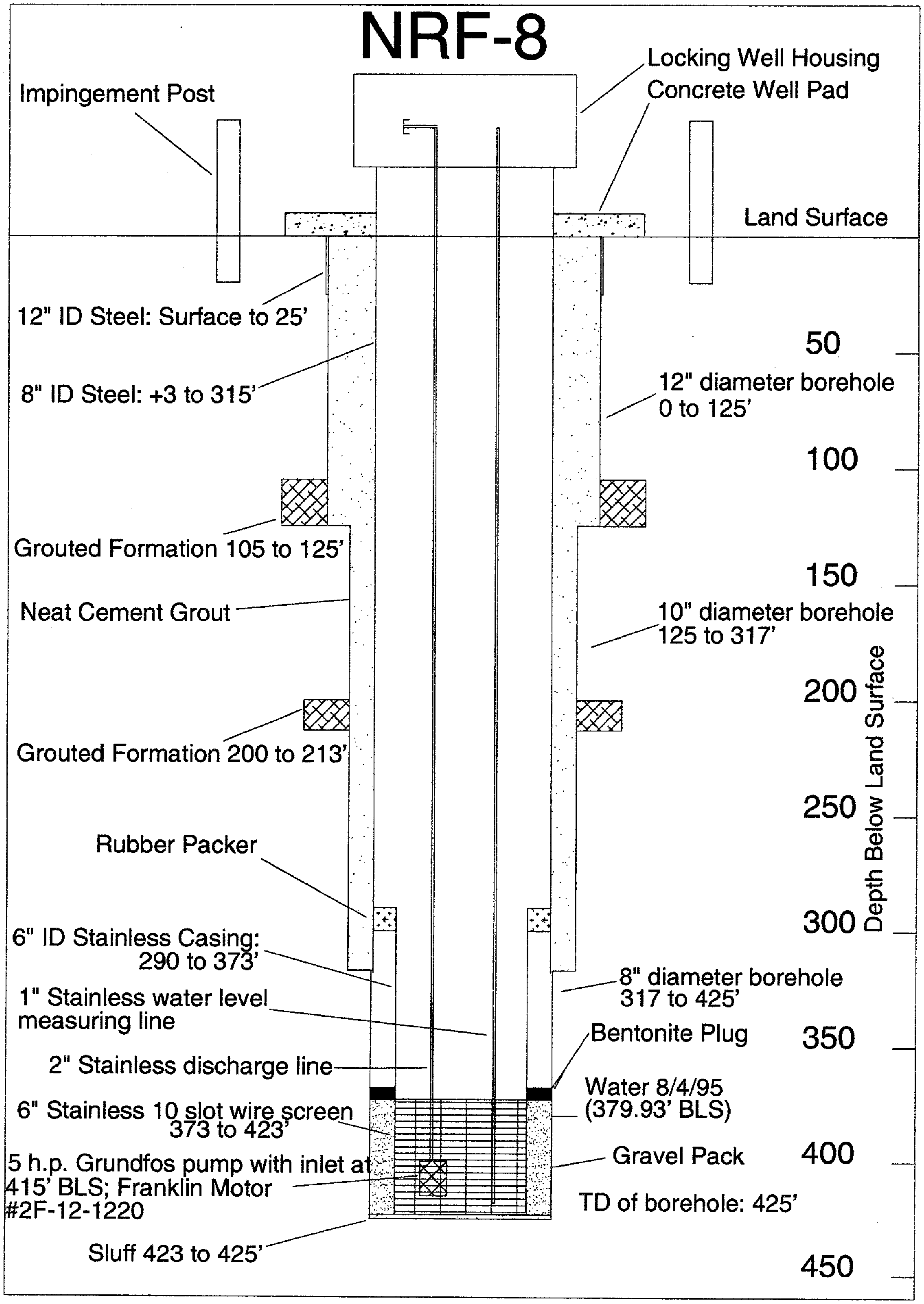

Figure 4 Typical Groundwater Well Construction Diagram

Soil gas monitoring was initiated and conducted periodically after the landfill cover had been placed at each location, to help assess the effectiveness of the landfill cover and to detect any potential gaseous contaminant migration. The monitoring included a soil gas emissions survey over the landfill cover and the placement of permanent soil gas monitoring probes around the perimeter of the landfill areas for the collection and analysis of subsurface soil gas samples. The soil gas emissions survey was utilized to assess the effectiveness of the landfill cover. The soil gas monitoring probes were used to detect any potential gaseous contaminant migration. Details of the soil gas monitoring are included in the Operation and Maintenance Plan (WEC 1997). The soil gas probes were designed with a screened section at the top of the basalt or at the top of the fluvial/lacustrine layer, as applicable. A top removable sampling assembly is attached to the probe opening for access during sampling evolutions.

The cost for the soil gas probe construction was $58,000. This included the cost for the placement of the concrete pads, benchmarks, and corner posts.

4.2.3.3 As Built Discussion

Soil gas monitor probes were installed after the placement of the final topsoil layer at each landfill. The auger rig used a 4 inch hollow stem auger that produced a 6 inch diameter hole. Monitoring locations were selected and staked prior to drilling. Fourteen monitor probes were installed in accordance with the specification as modified by an Engineering Change Notice. The changes included a PVC casing size change from 0.75 inch OD to 1.05 inch OD (0.75 inch ID), surface protective casing size change from 3 inch to 6 inch, increasing the bentonite seal from 3 inches to 3 feet, and use of 8-12 silica sand instead of 8-10 silica sand. Figure 5 depicts the typical soil gas monitor probe construction. Locations of the monitor probes are indicated on the as-built drawings for each landfill in the Remedial Action Report (WEC 1996).

Borings were advanced to depths as determined by the presence of fluvial/lacustrine deposits or the presence of basalt. Monitor probe depths by landfill unit are summarized in Table 5. Daily drilling construction reports and lithology logs for the monitor probe installations are provided in the Remedial Action Report (WEC 1996).

Table 5 Gas Probe Installation Depths

Landfill Unit	Probe Designation	Final Depth (ft)
8-05-1	MW1-1	22.0
	MW1-2	26.5
	MW1-3	18.5
	MW1-4	25.5
8-05-51	MW51-1	13.5
	MW51-2	23.0
	MW51-3	13.0
	MW51-4	15.5
8-06-53	MW53-1	21.5
	MW53-2	24.5
	MW53-3	24.0
	MW53-4	18.5
	MW53-5	12.5
	MW53-6	12.5

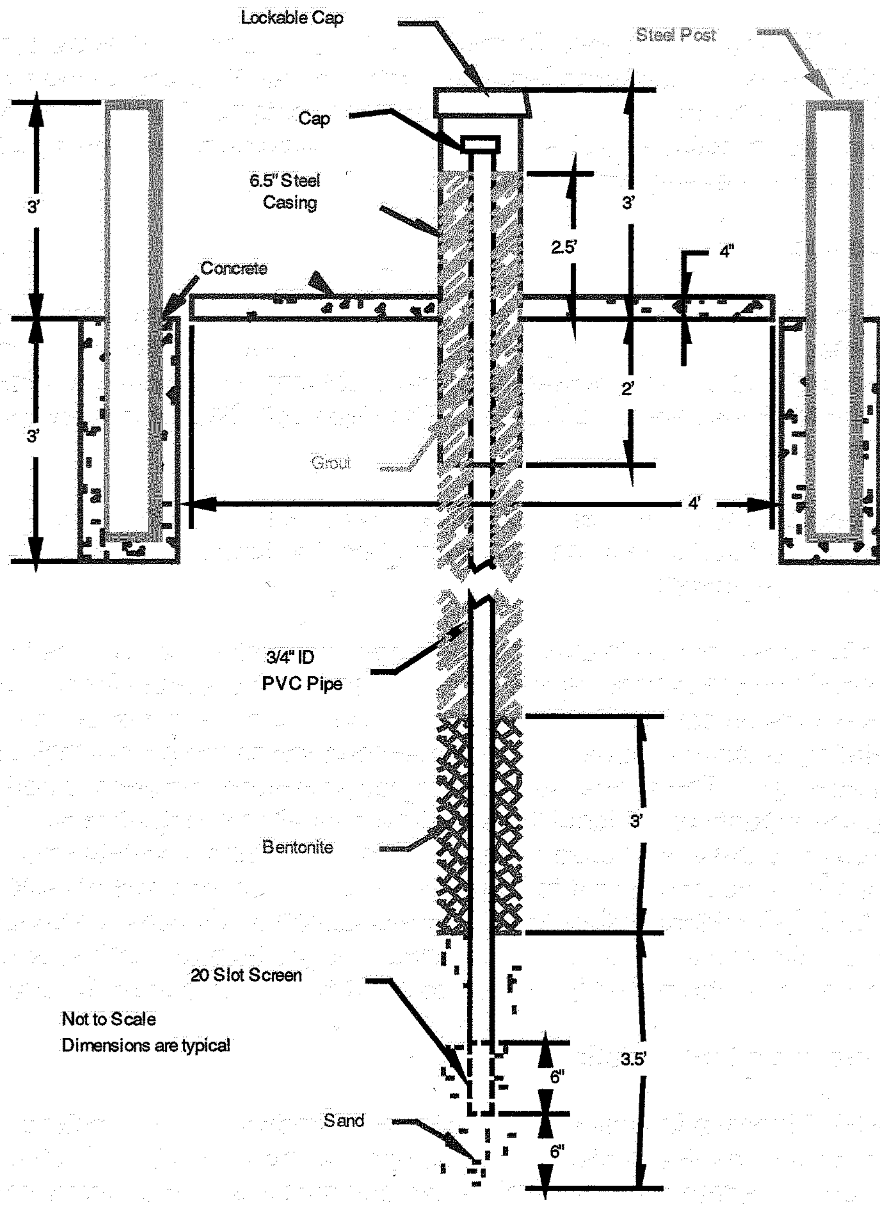

Figure 5 Typical Soil Gas Probe Construction Diagram

Protection of the monitor probes was achieved through the installation of 6-inch steel casings with lockable caps. Each monitoring probe was fitted with a brass identification tag embedded in the concrete pad. On completion of the soil gas monitoring probe installation, each of the 14 monitoring probe locations were surveyed using the brass tag locations.

4.3 System Operations

As part of the Industrial Waste Ditch and Landfill Areas ROD, three remedies were selected with respect to the landfill areas. These remedies were to cap the landfills, and to monitor the soil gas and groundwater. Each remedy requires system O&M costs as discussed below. Operation costs include collecting and analyzing samples. Maintenance costs include upkeep of the system and routine preventative maintenance.

4.3.1 Landfill Covers

After the completion of the remedial action construction phase for the landfill areas, the next step included a management phase or systems operations phase. The systems operations that are presently being undertaken were presented in the O&M plan included in the Final Remedial Action Report for the NRF Inactive Landfill areas. The O&M activities for the covers consist of the following tasks:

Annual inspection and maintenance of the landfill covers to control erosion
Annual sampling of surface soil gas emissions from the landfill covers
General area maintenance

The annual inspection is performed to check for any signs of erosion that may have occurred and to check the condition of the vegetative cover. This includes checking for any signs of subsidence, signs of erosion caused by wind or storm-water runoff, and indications of bare spots, dead vegetation, or animal intrusions. The maintenance on the covers includes any restoration work necessary. The annual surface soil gas emissions sampling is performed to assist in checking the integrity of the landfill cover. The annual sampling consists of taking readings at the surface of the landfill covers at various locations with a portable hand-held monitor. The total annual operation cost for conducting the inspections and emissions survey is approximately $300 (predominantly labor costs). The occasional maintenance conducted since cover completion is estimated to be $6,000 (this included a one time re-seeding of the landfill covers). The total cost over the period from 1997 to 1999 is estimated to be $6,900.

4.3.2 Groundwater Monitoring Wells

Since signing the NRF Inactive Landfill Areas ROD, the groundwater monitoring system has consisted of thirteen wells, each sampled four times per year by the USGS. Each quarter, one blank sample and one duplicate sample are collected and sent in with the normal samples. Samples are analyzed at USGS-contracted laboratories. Once received by NRF, sample results are sent to an independent contractor for data validation. At NRF, a representative coordinates the collection, analysis, validation, and interpretation of all groundwater samples. The breakdown of costs associated with the groundwater monitor portion of the landfill remedy are summarized in Table 6.

Table 6 Yearly Operational Costs for Groundwater Monitoring Network				
Time Period	Analysis Costs	Validation Costs	Maintenance	Yearly Total
11/95 to 1/96	$22,500	$2,250	$400	$25,150
1996	$90,000	$9,000	$800	$99,800
1997	$110,000	$9,700	$800	$120,500
1998	$108,000	$9,700	$800	$118,500
1999	$108,000	$9,700	$800	$118,500
1/00 to 10/00	$81,000	$10,200	$400	$91,600
Subtotal	$519,500	$50,550	$4000	
			Five Year Total	**$574,050**

4.3.3 Soil Gas Monitoring Wells

The specific O&M activities associated with soil gas monitoring of the landfill areas includes sampling a total of thirteen soil gas monitoring probes (one probe is inoperative), analytical costs, data validation, and any maintenance costs. The soil gas monitoring probe locations are sampled on a quarterly basis. This includes 13 samples from the soil gas monitoring probes, one duplicate, one field air blank, and one field equipment blank. The samples are sent off-site and analyzed by the contract laboratory. The analytical results are then submitted for data validation. After the results are validated, NRF evaluates the data for any problems and for trends. The breakdown of the costs associated with the soil gas monitoring tasks are tabulated in Table 7.

Table 7 Yearly Operational Costs for Soil Gas Monitoring				
Time Period	Analysis Costs	Validation Costs	Maintenance	Yearly Total
1996	$5,000	$100	$0	$5100
1997	$20,000	$1,600	$500	$22,600
1998	$20,000	$1,600	$500	$22,100
1999	$20,000	$1,600	$500	$22,100
1/00 to 10/00	$15,000	$1,200	$300	$16,500
Subtotals	$80,000	$6,100	$1800	
			Five Year Total	**$88,400.00**